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Dalvi

(54) **PULSER WITH DOUBLE-BEARING POSITION ENCODER FOR NON-INVASIVE PHYSIOLOGICAL MONITORING**

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(58) **Field of Classification Search**

CPC ... G01D 5/34738; G01D 11/02; A61B 5/1455

See application file for complete search history.

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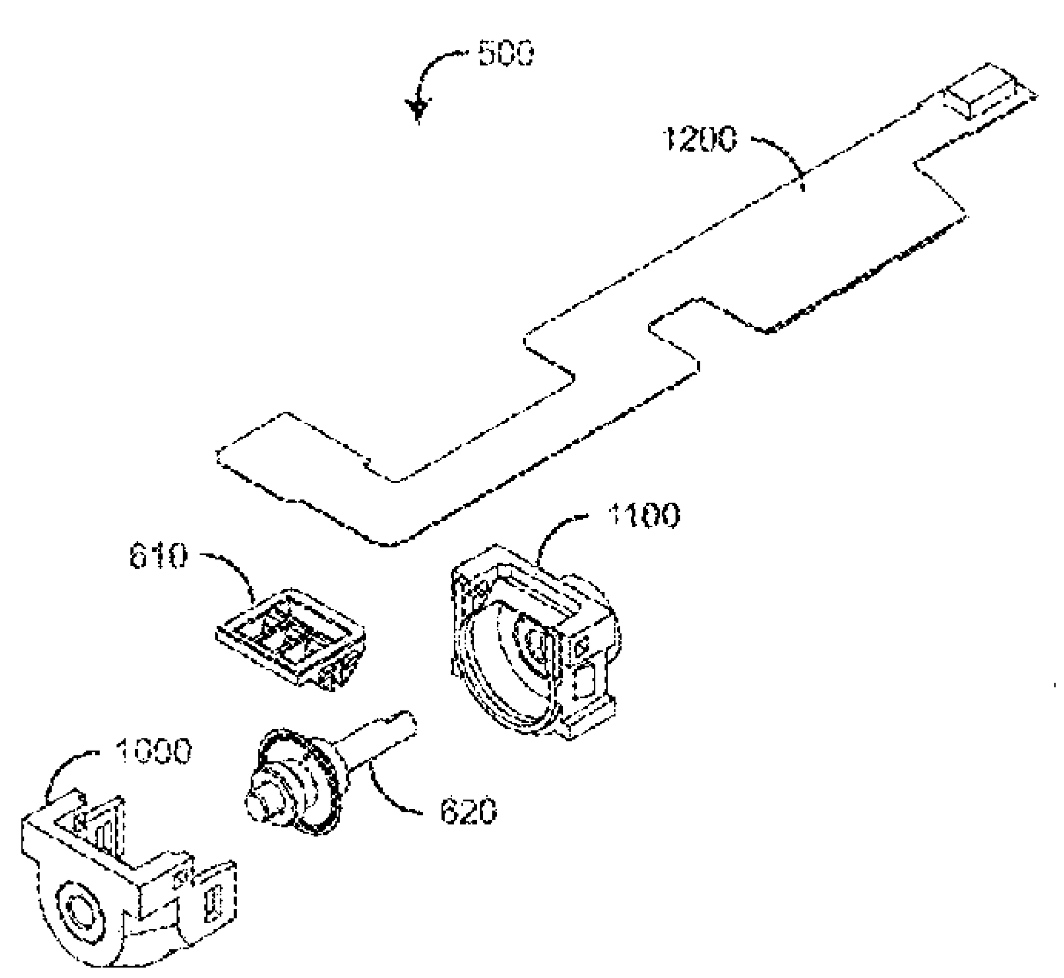
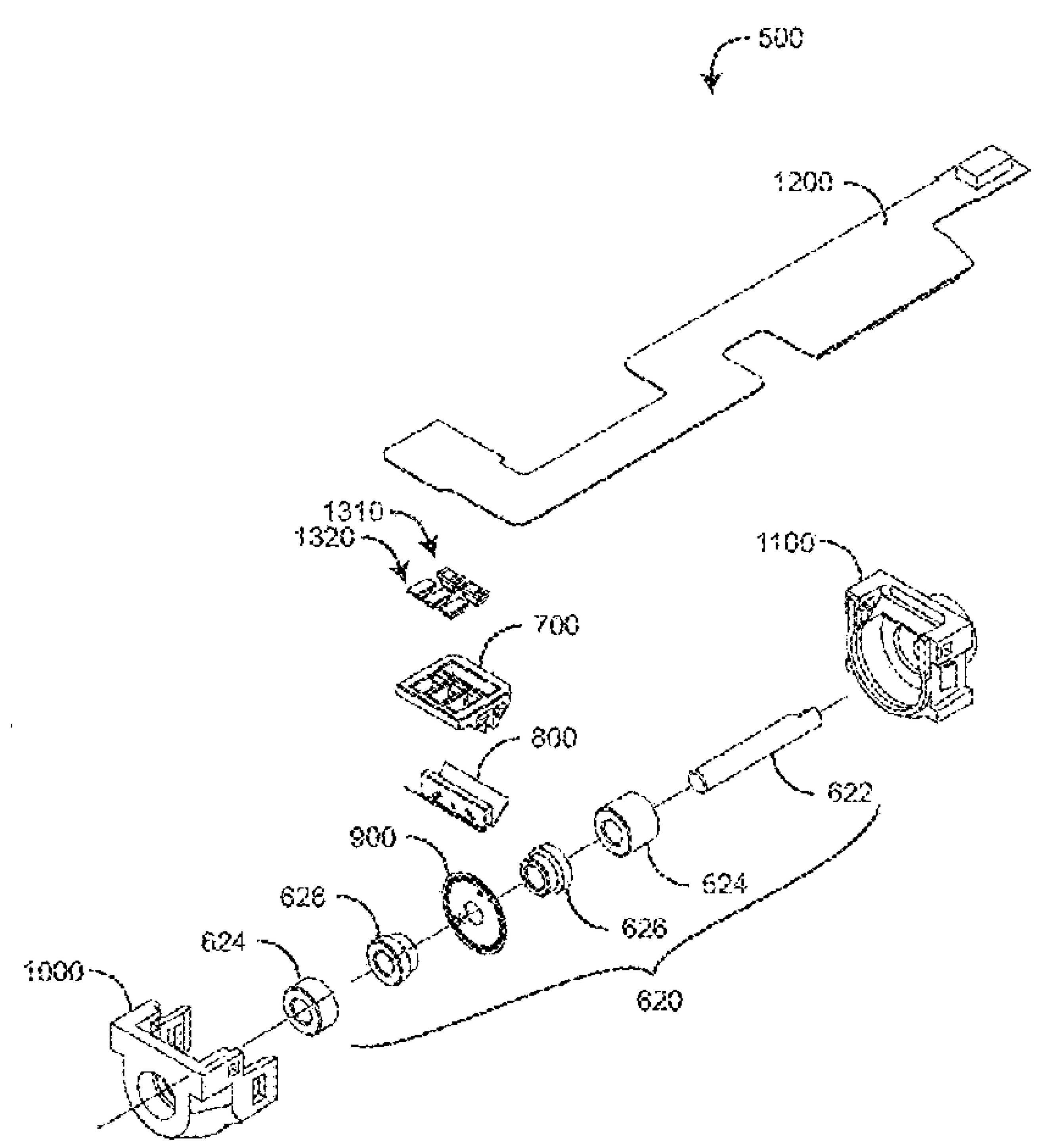
(57) **ABSTRACT**

A double-bearing position encoder has an axle stabilized within a housing via two bearings disposed on opposite walls of the housing. The axle is in communications with a rotating cam. The cam actuates a pulser so as to generate an active pulse at a tissue site for analysis by an optical sensor. The axle rotates a slotted encoder wheel or a reflective encoder cylinder disposed within the housing so as to accurately determine the axle position and, hence, the active pulse frequency and phase.

19 Claims, 23 Drawing Sheets





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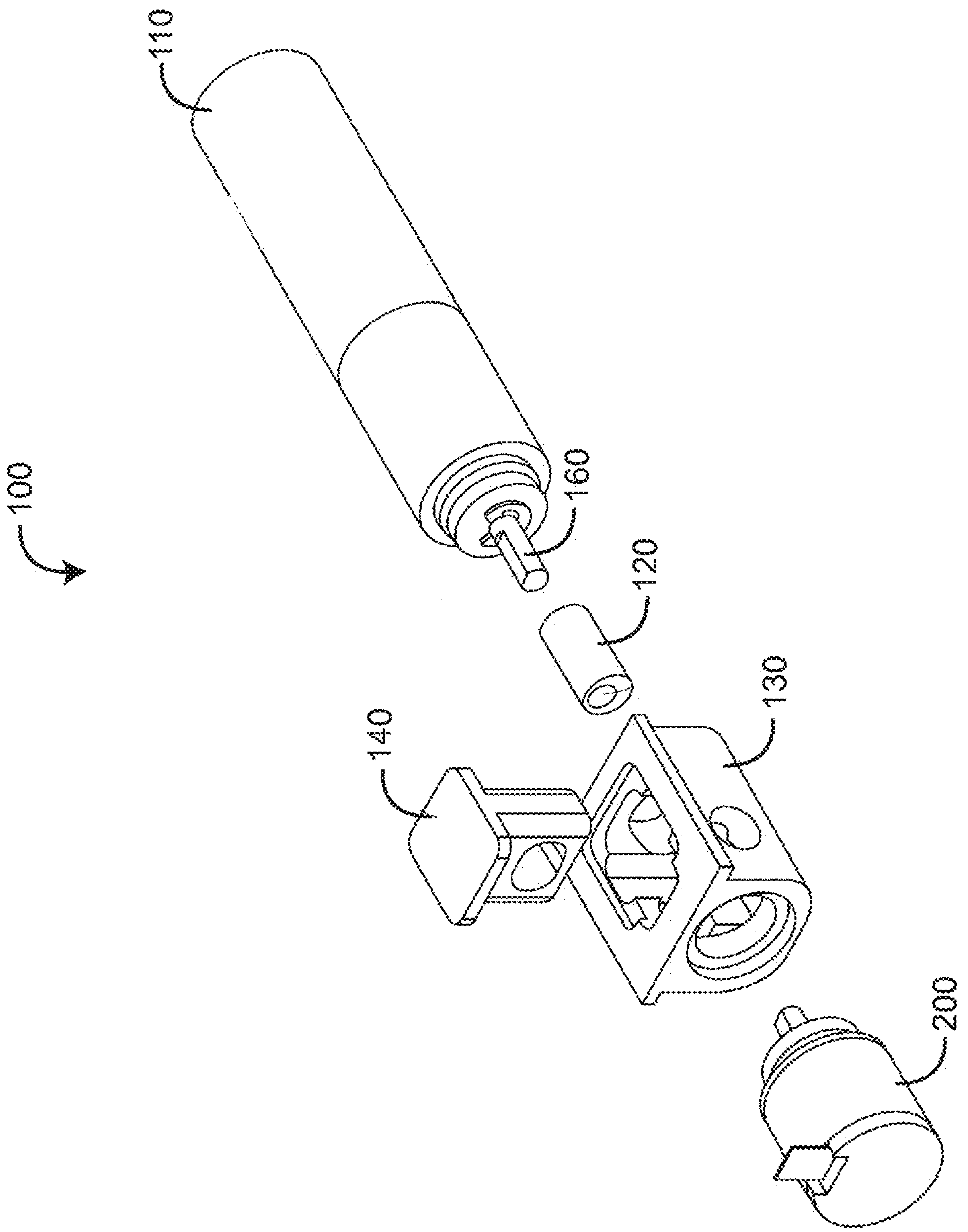

FIG. 1
(PRIOR ART)

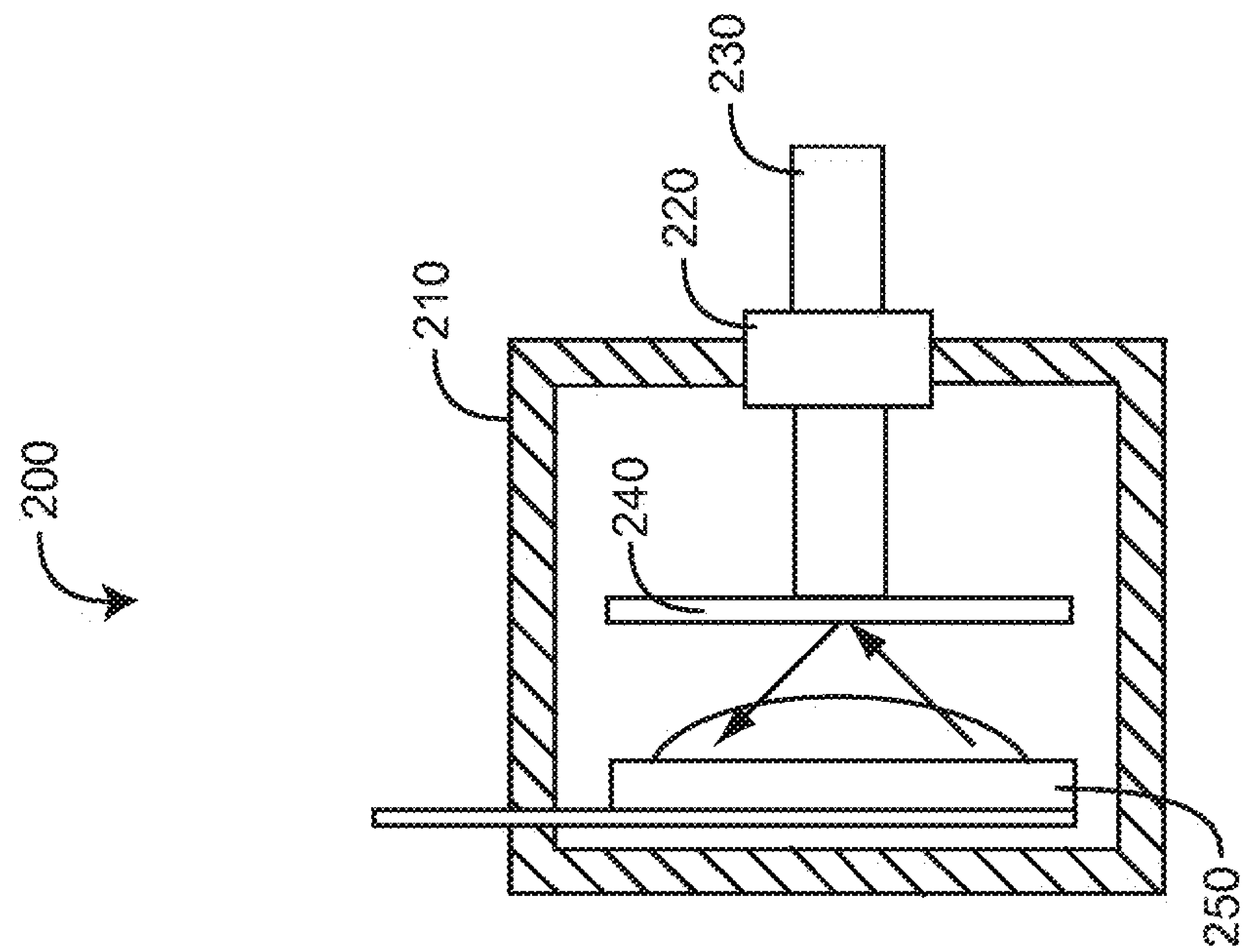

FIG. 2
(PRIOR ART)

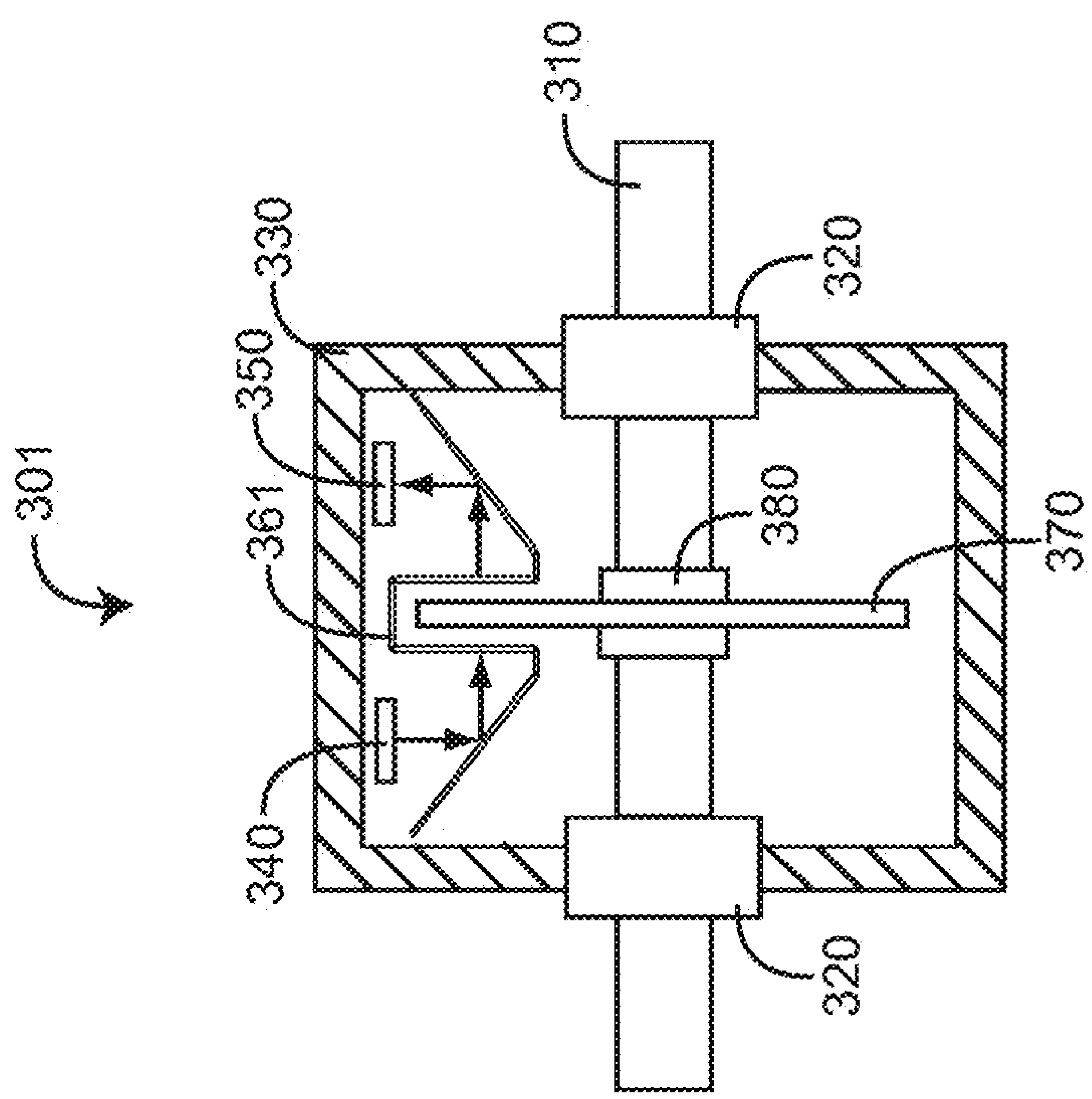
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FIG. 3A

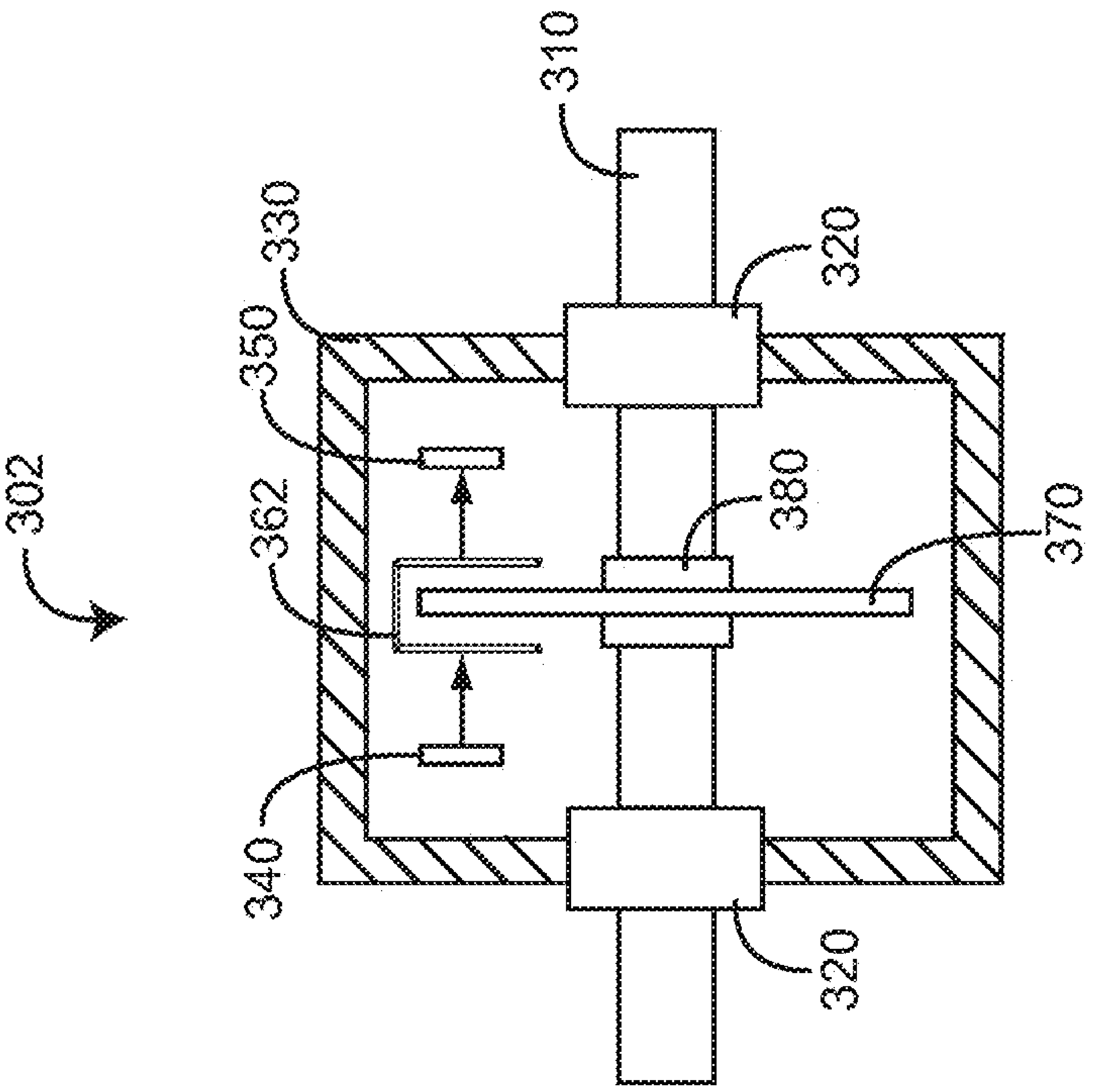
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FIG. 3B

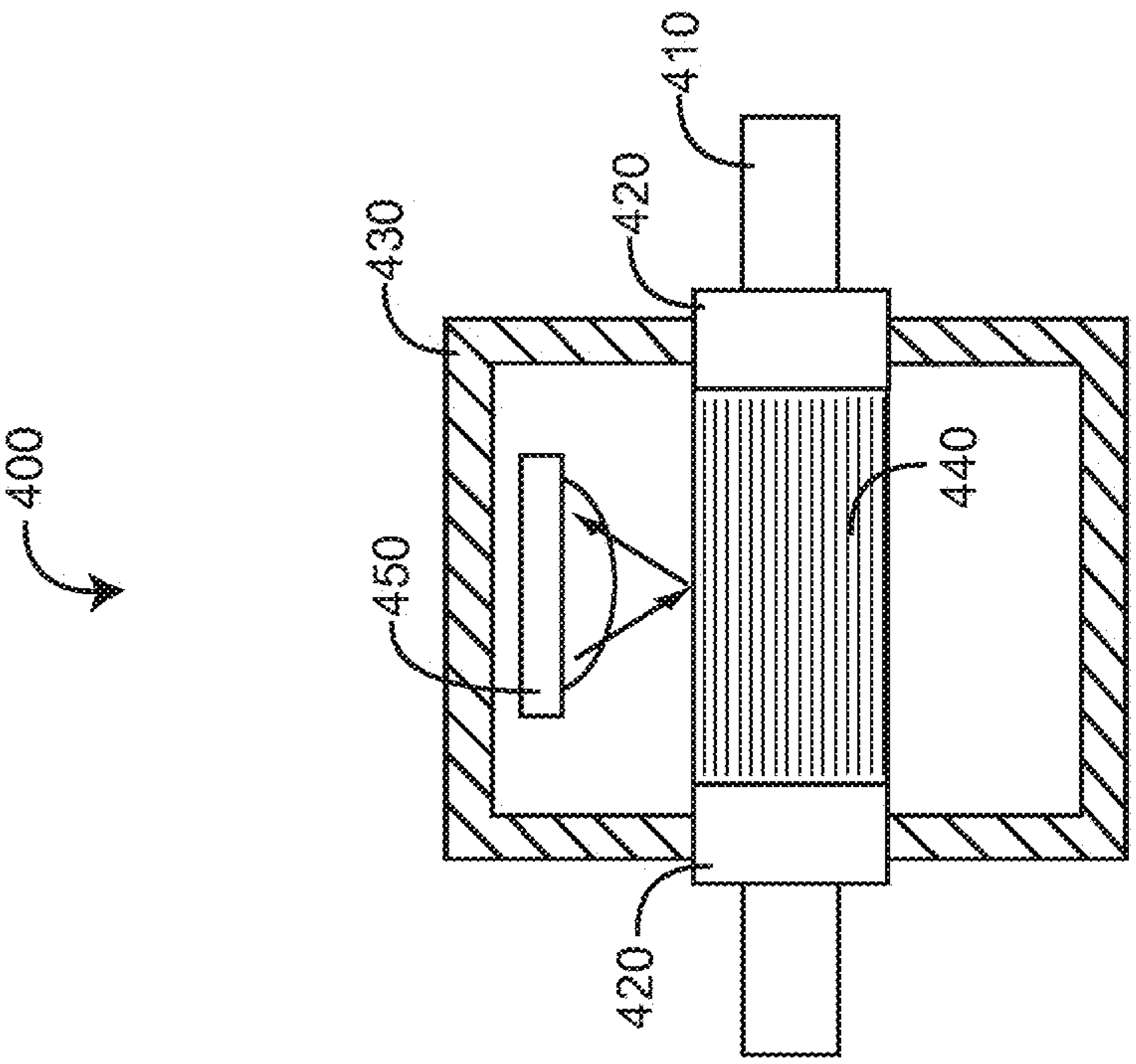

FIG. 4

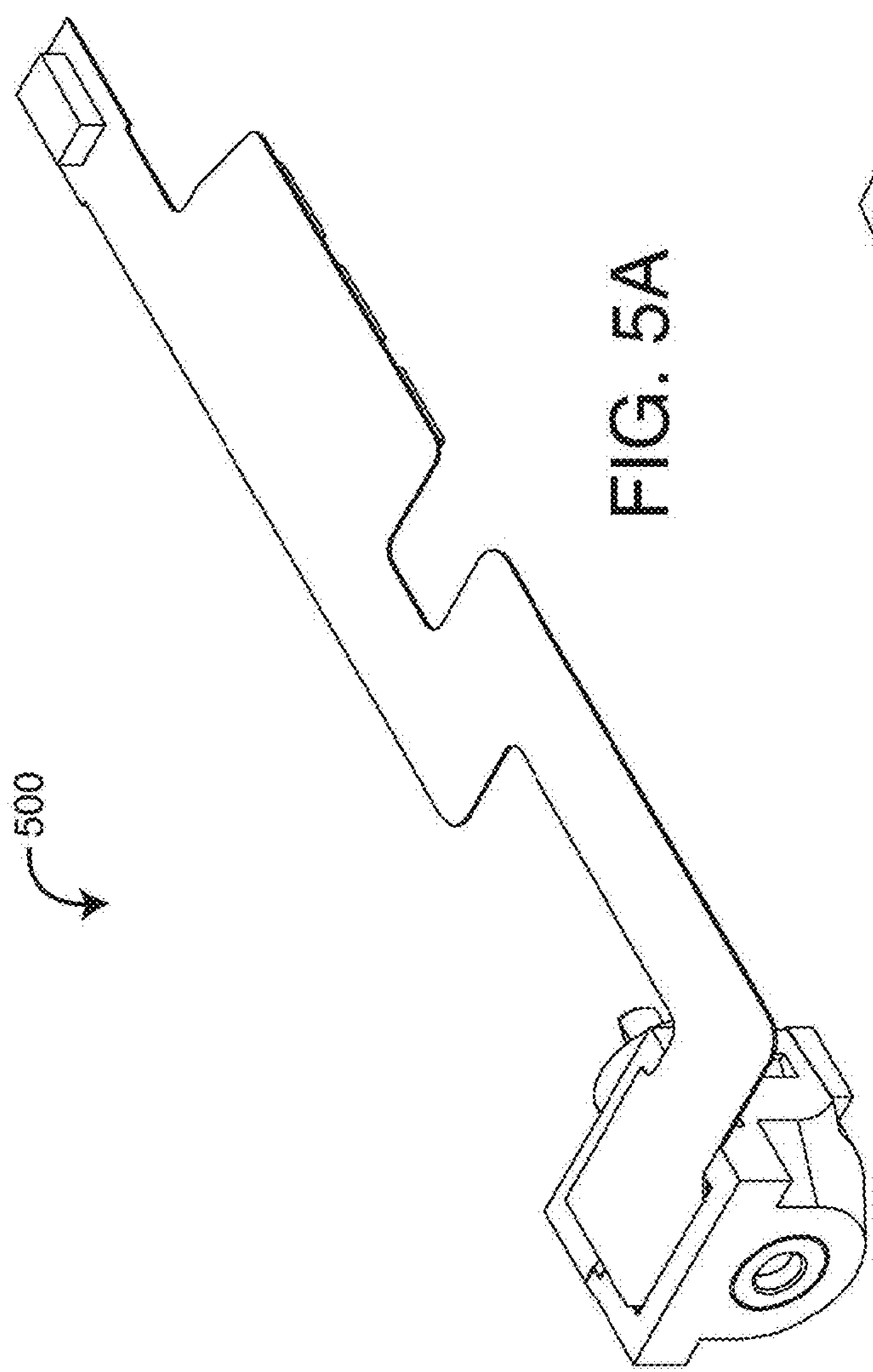

FIG. 5A

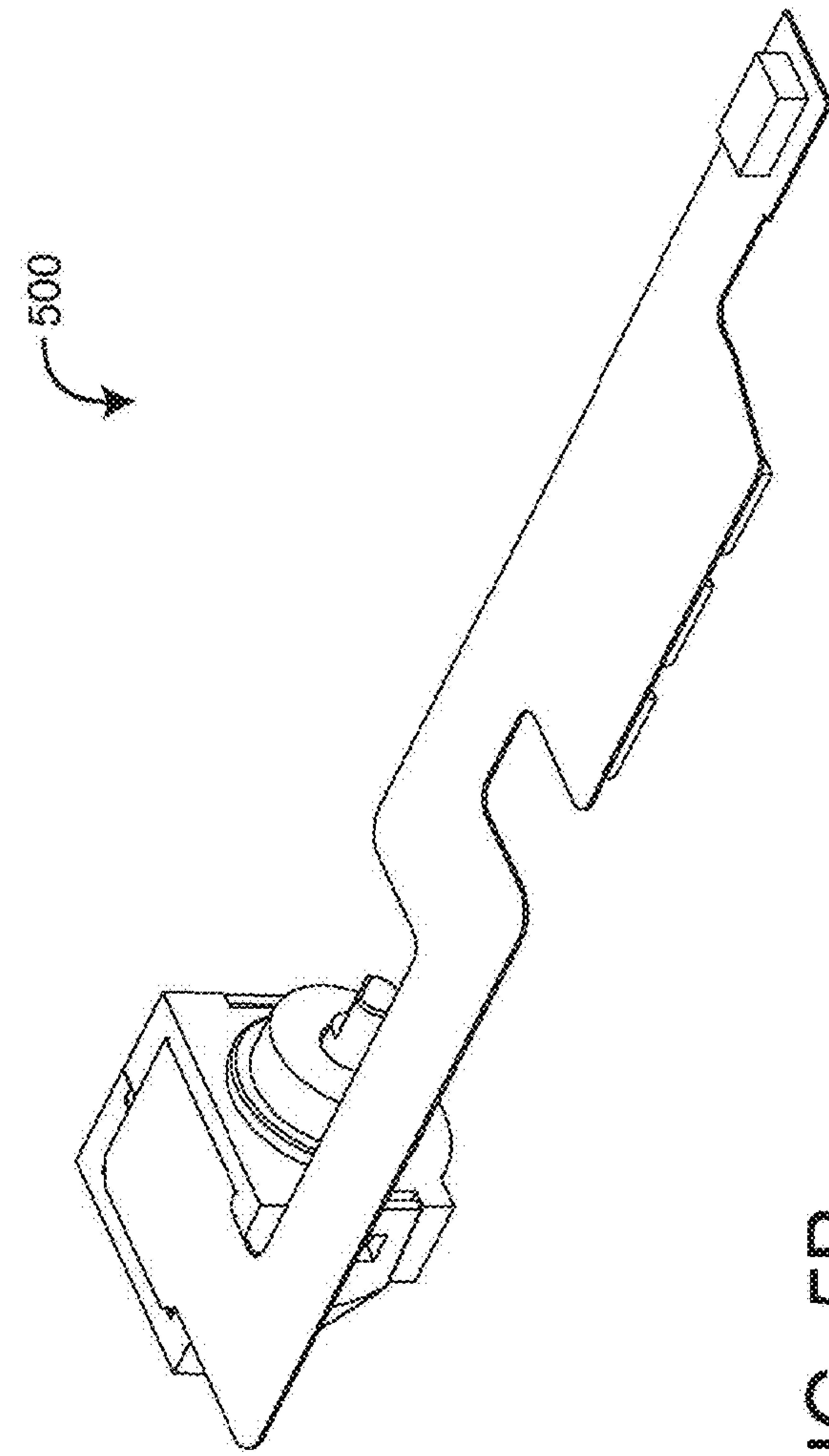

FIG. 5B

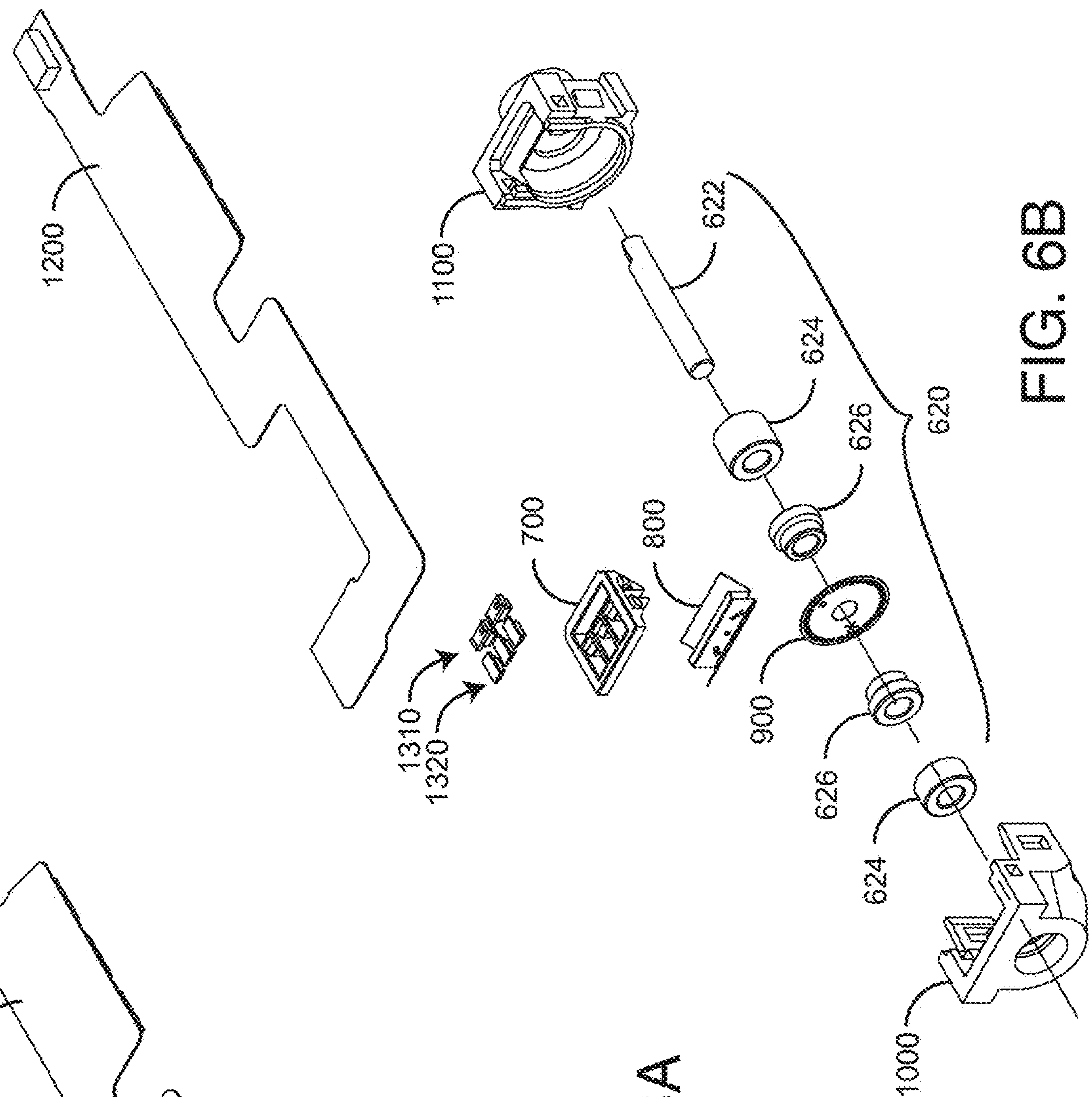
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FIG. 6B

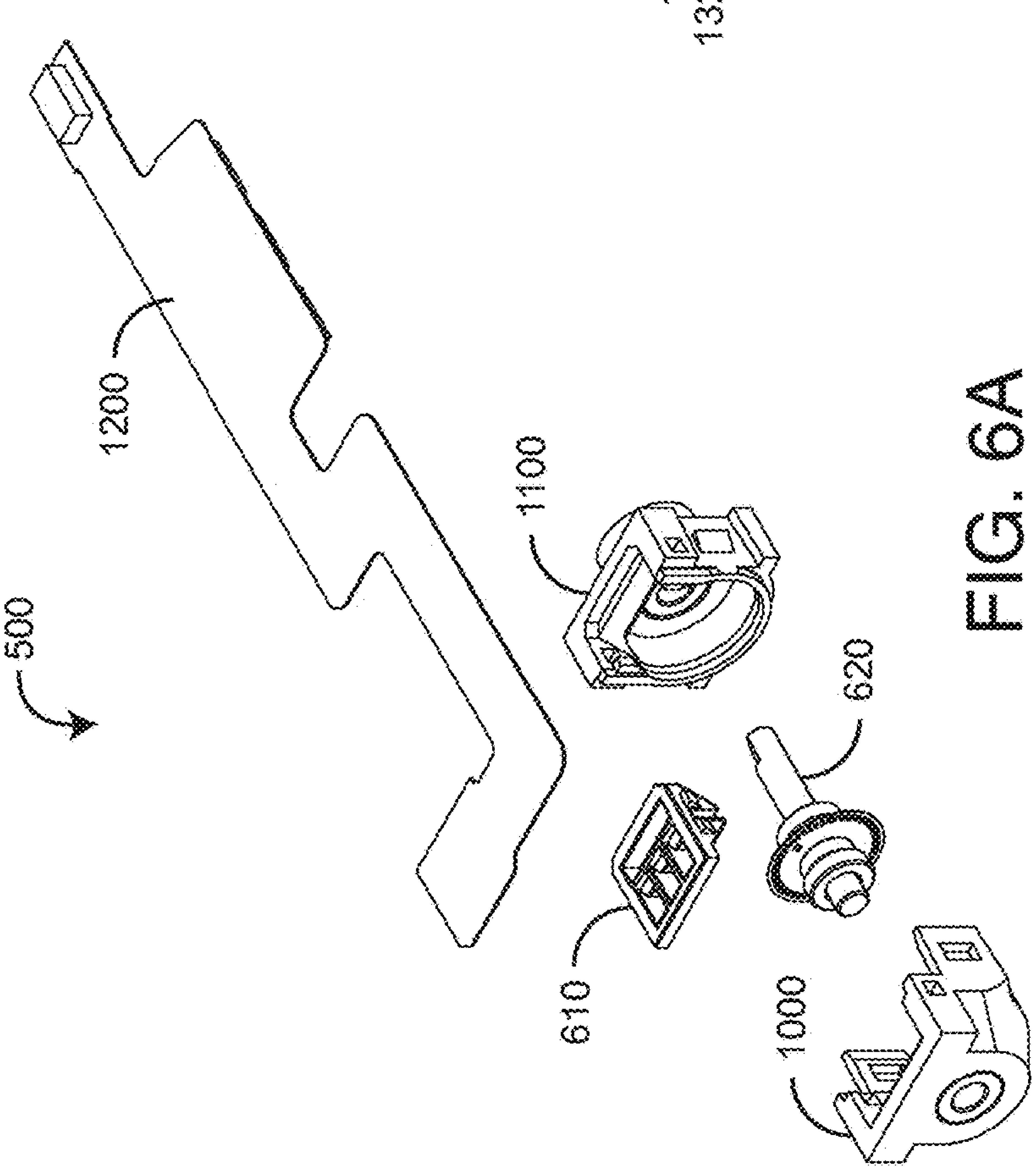
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FIG. 6A

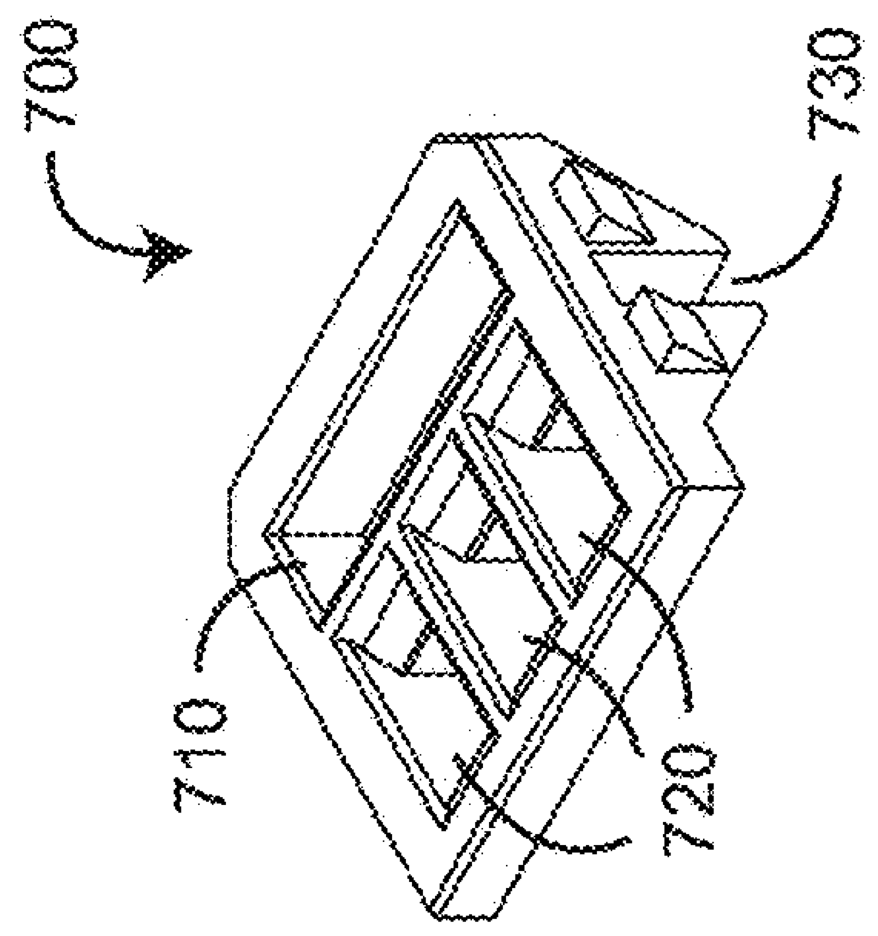

FIG. 7E

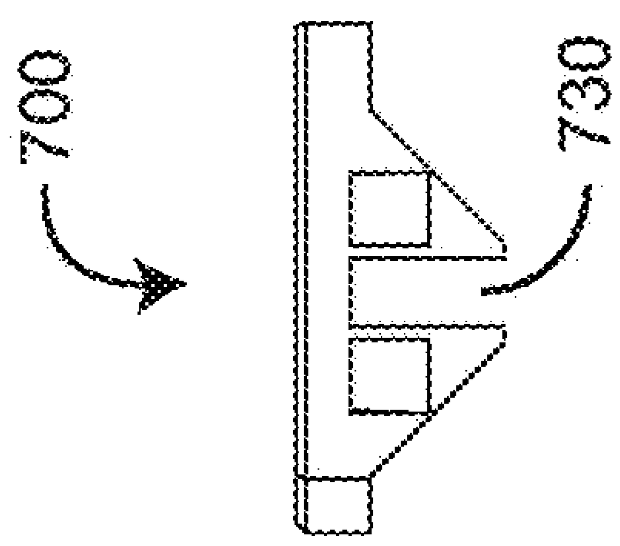

FIG. 7D

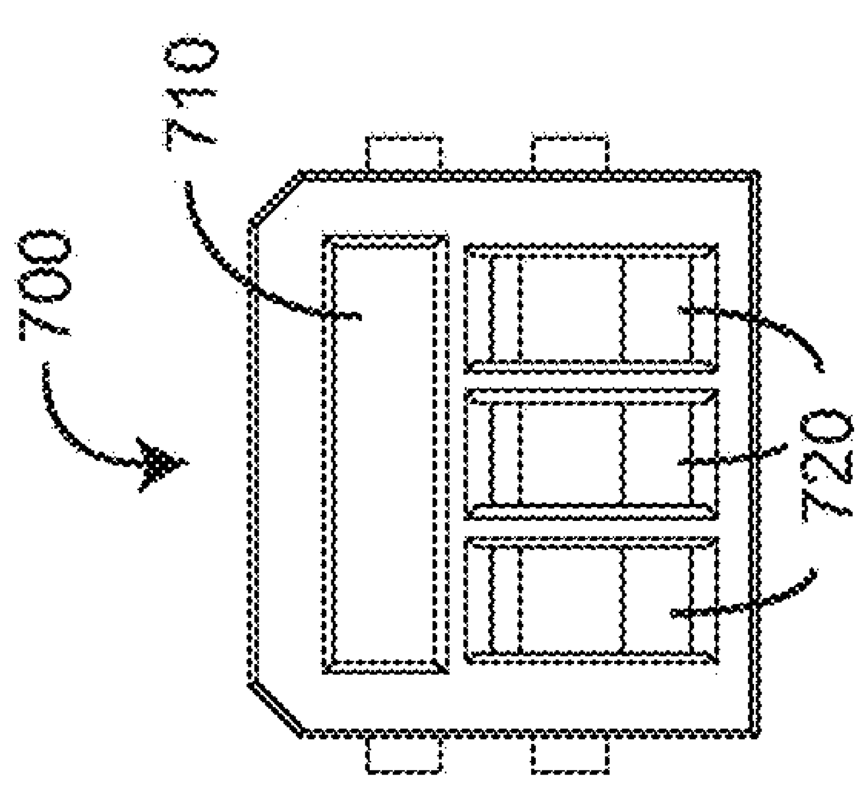

FIG. 7A

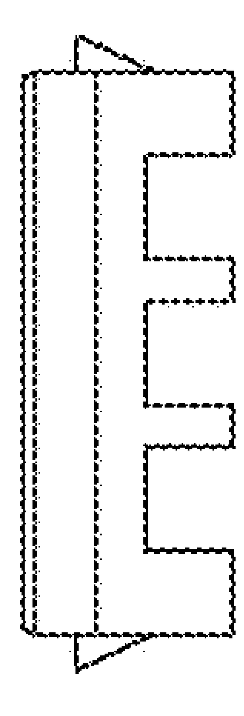
FIG. 7B

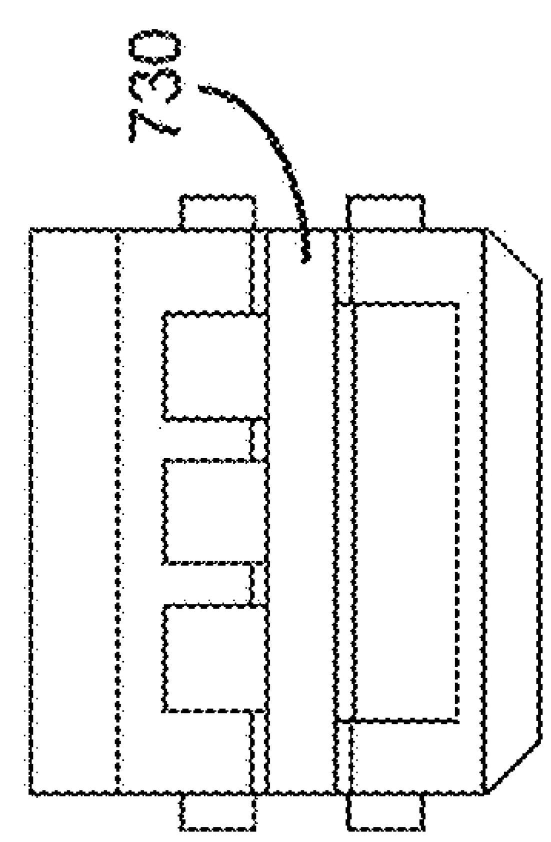

FIG. 7C

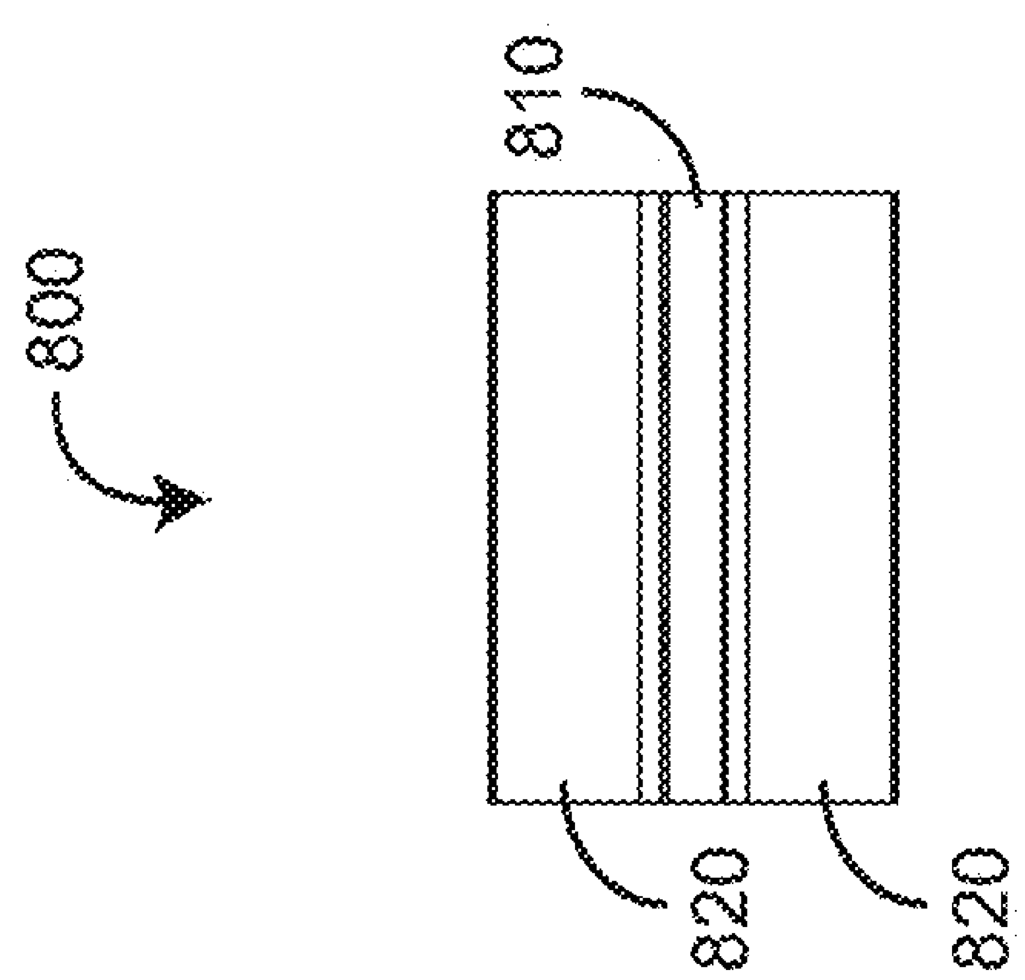

FIG. 8A

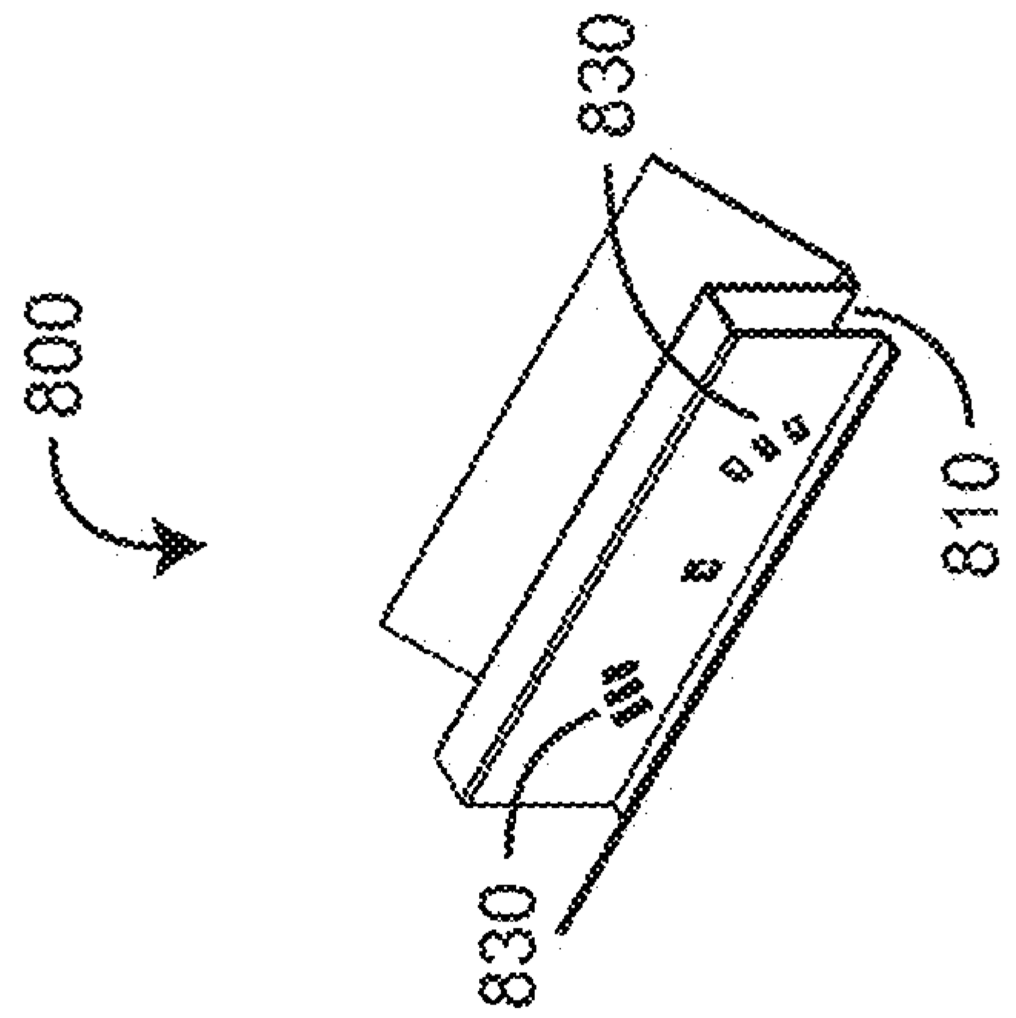

FIG. 8B

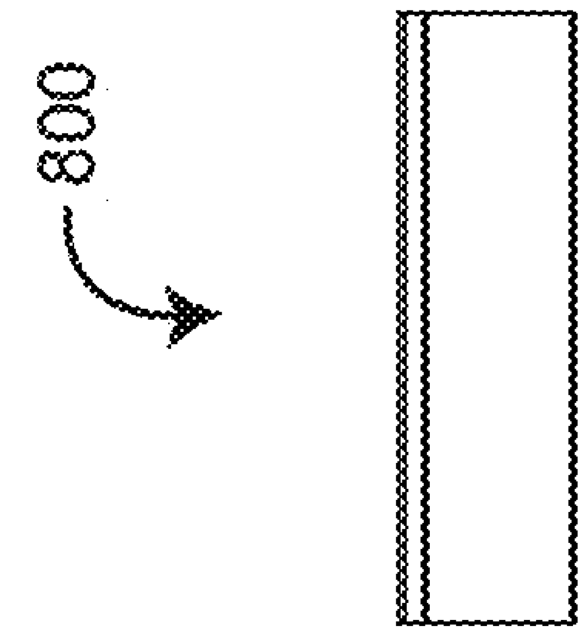

FIG. 8C

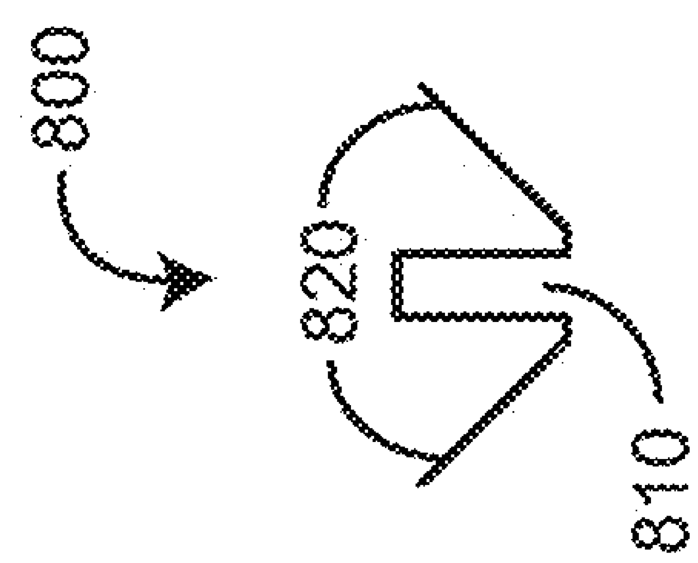

FIG. 8D

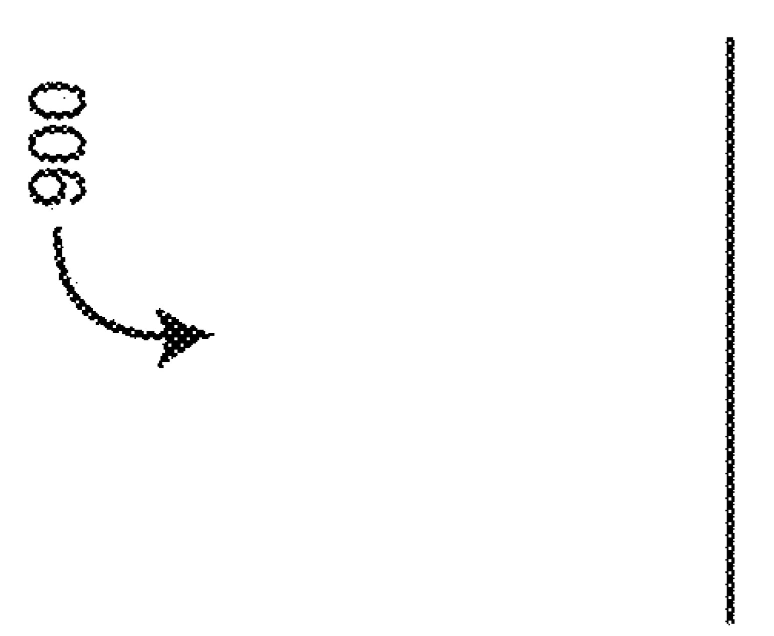

FIG. 9A

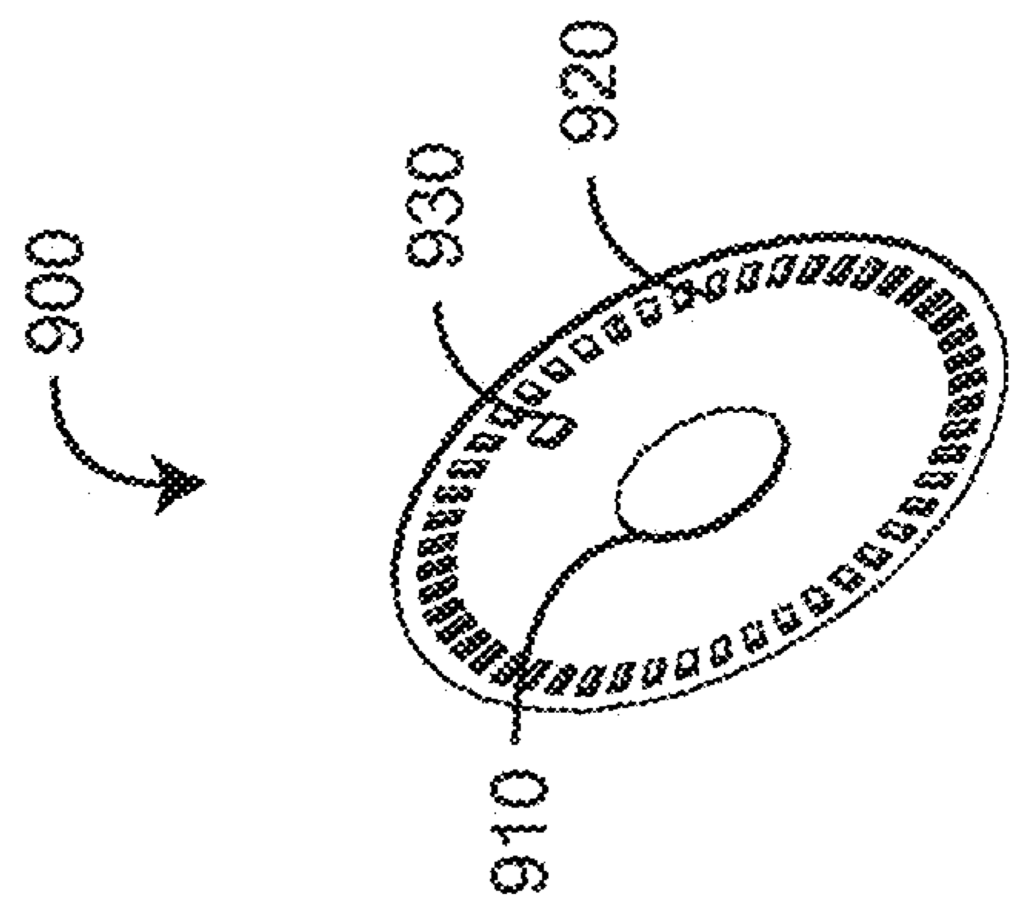

FIG. 9B

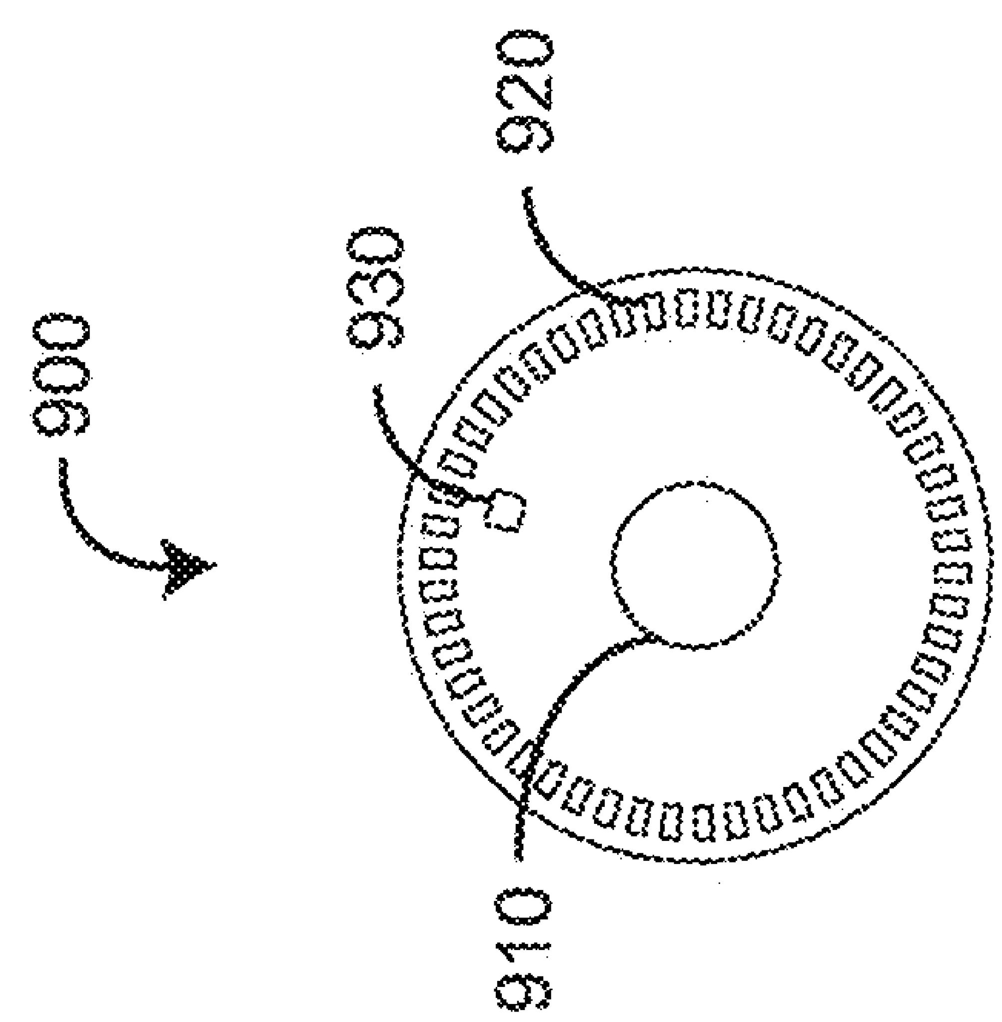

FIG. 9C

FIG. 9D

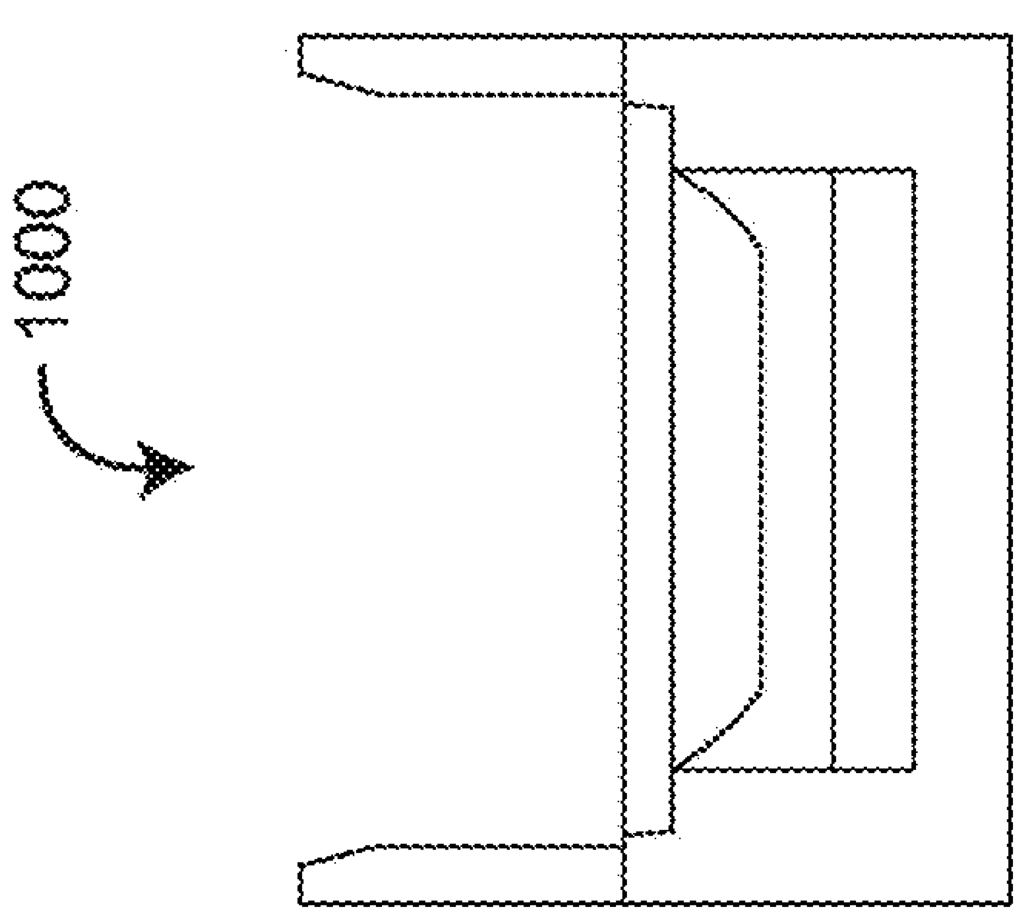

FIG. 10A

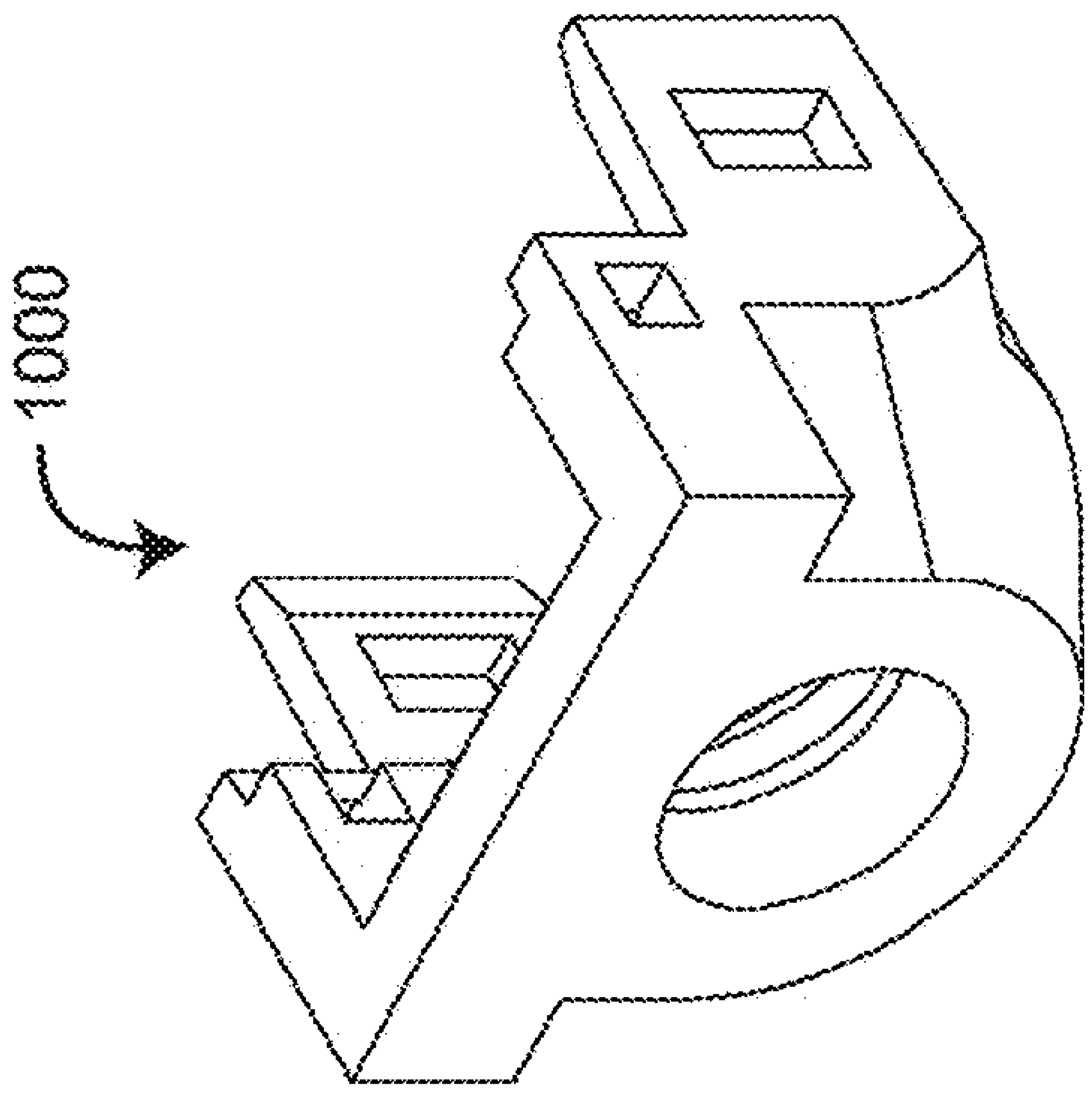

FIG. 10B

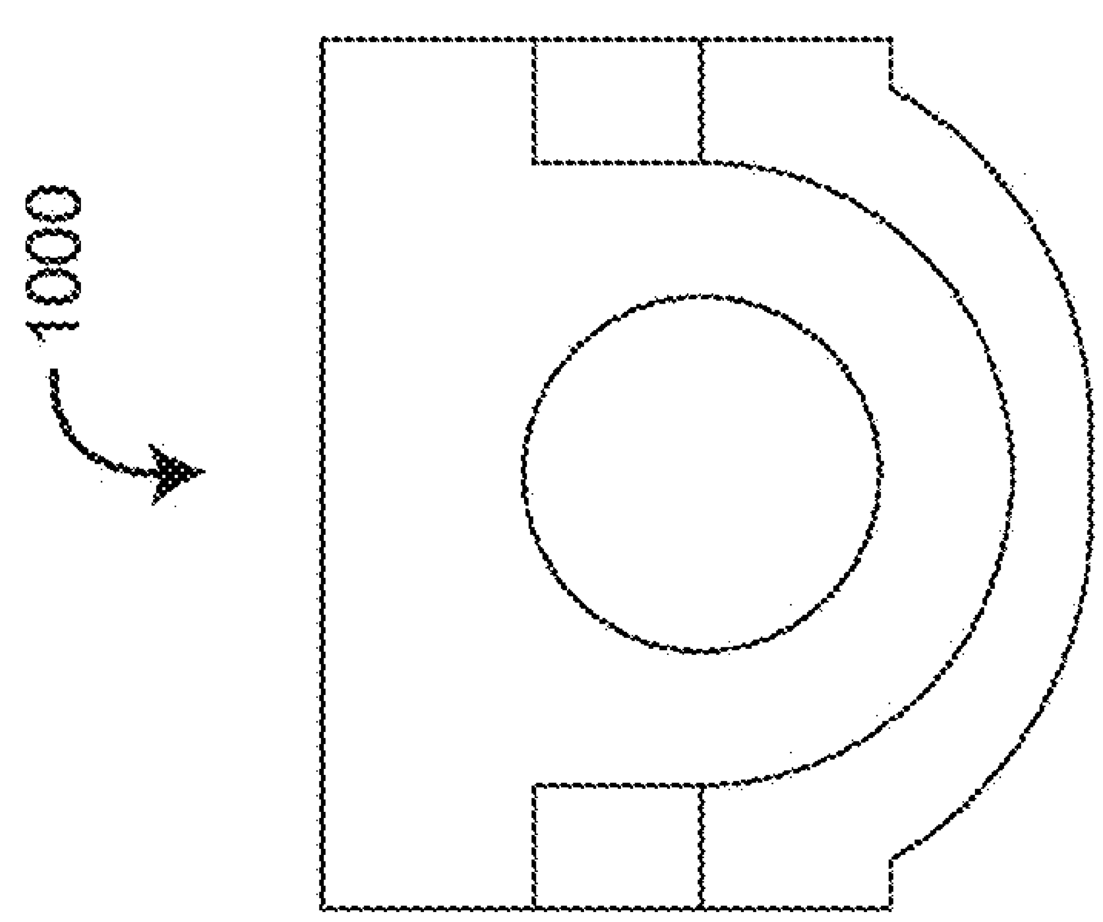

FIG. 10C

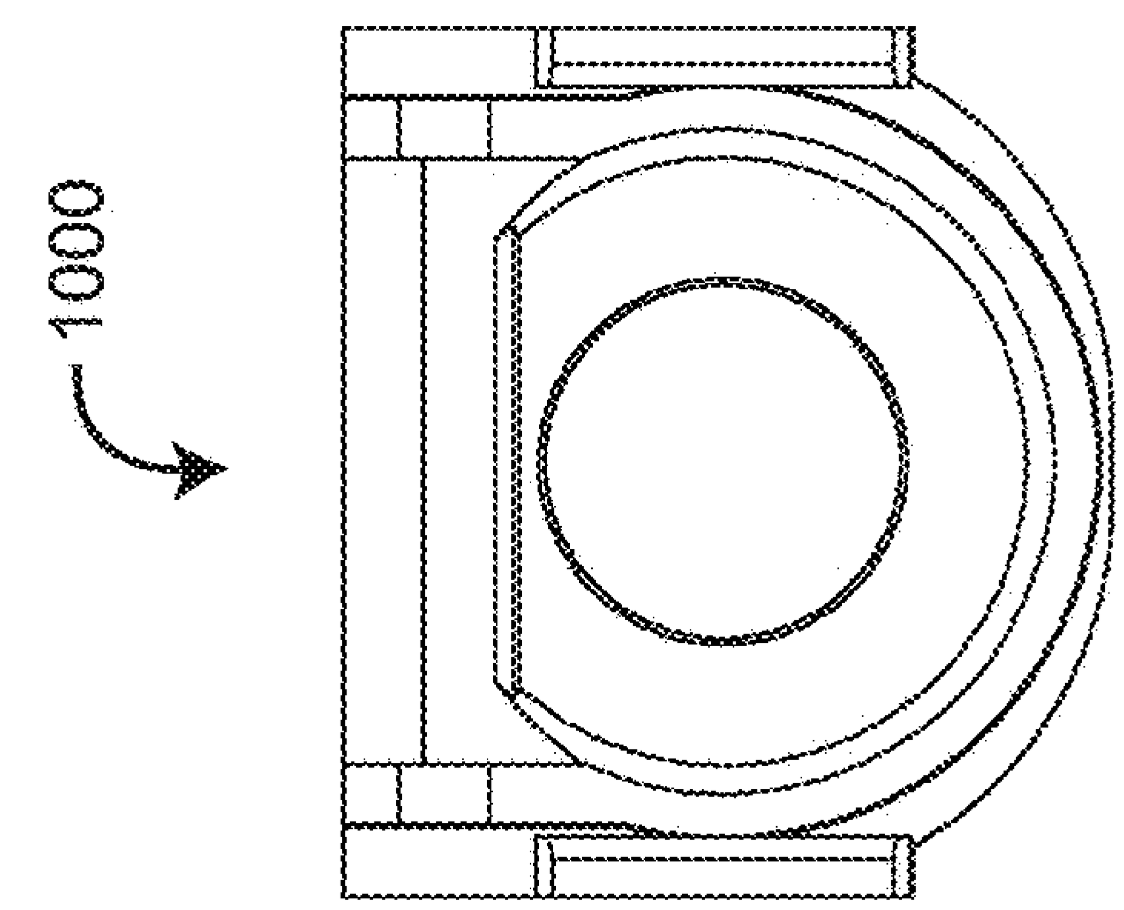

FIG. 10D

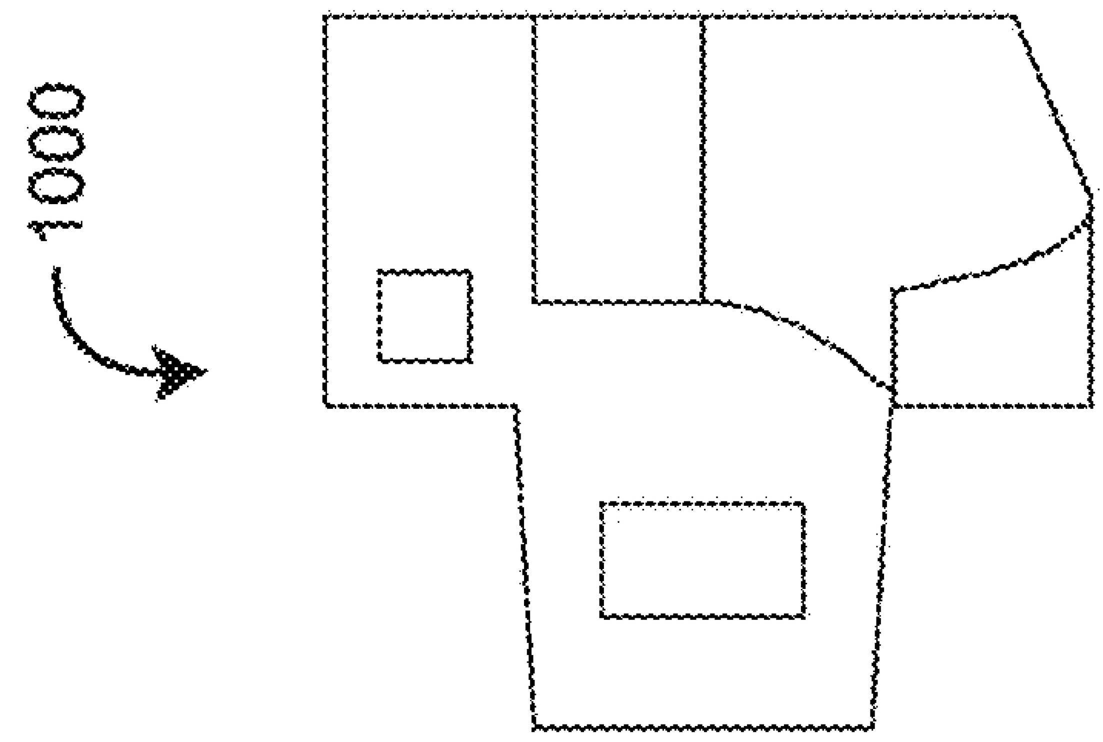

FIG. 10E

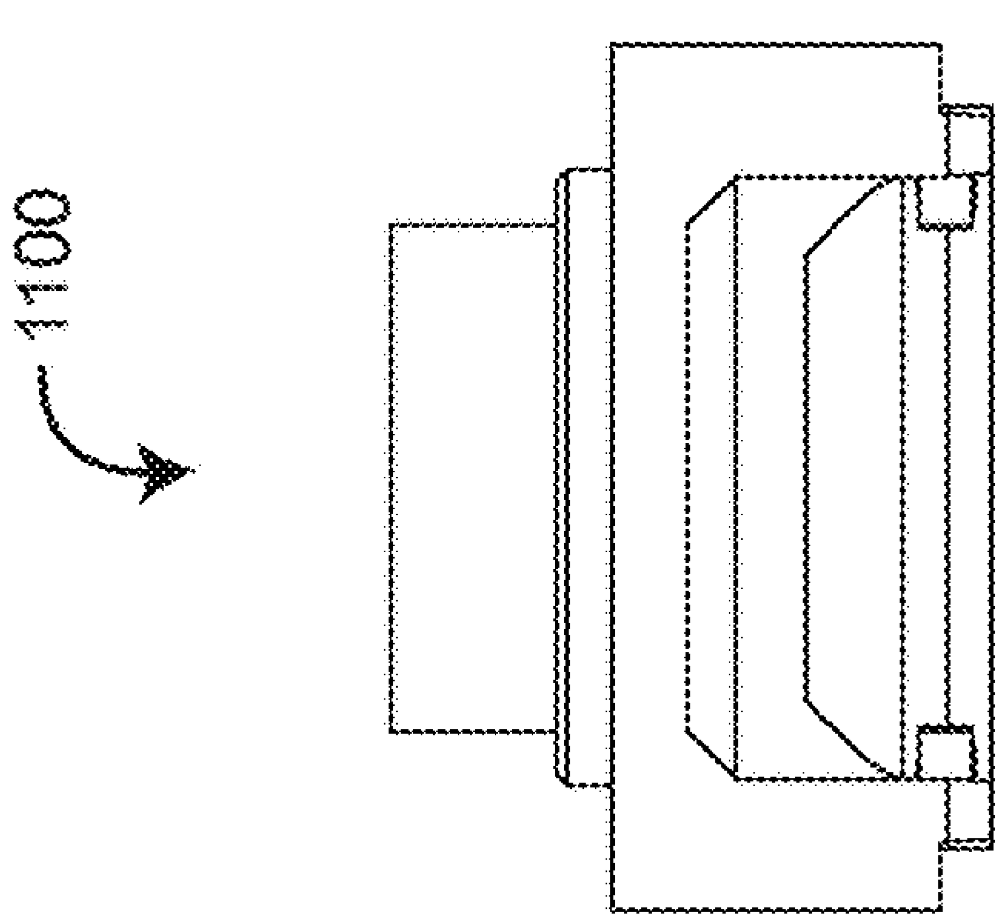

FIG. 11A

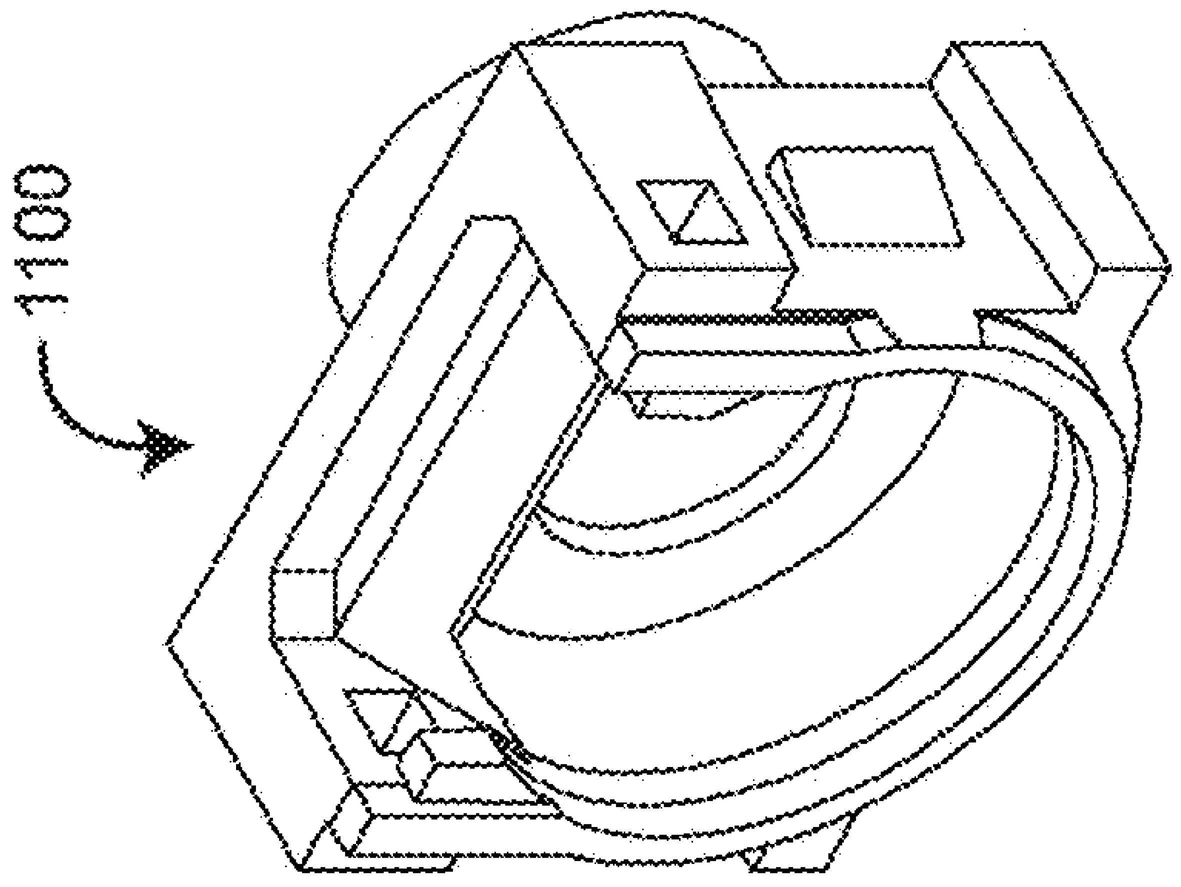

FIG. 11B

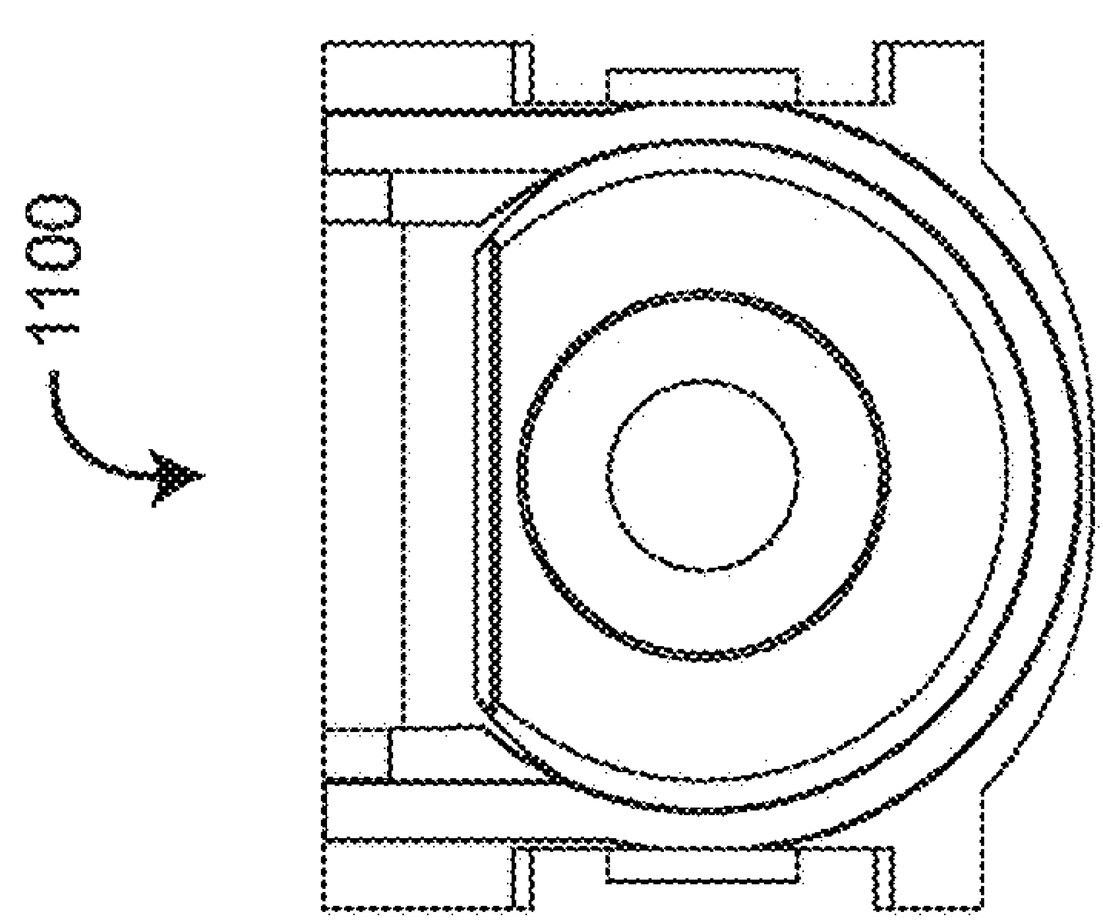

FIG. 11C

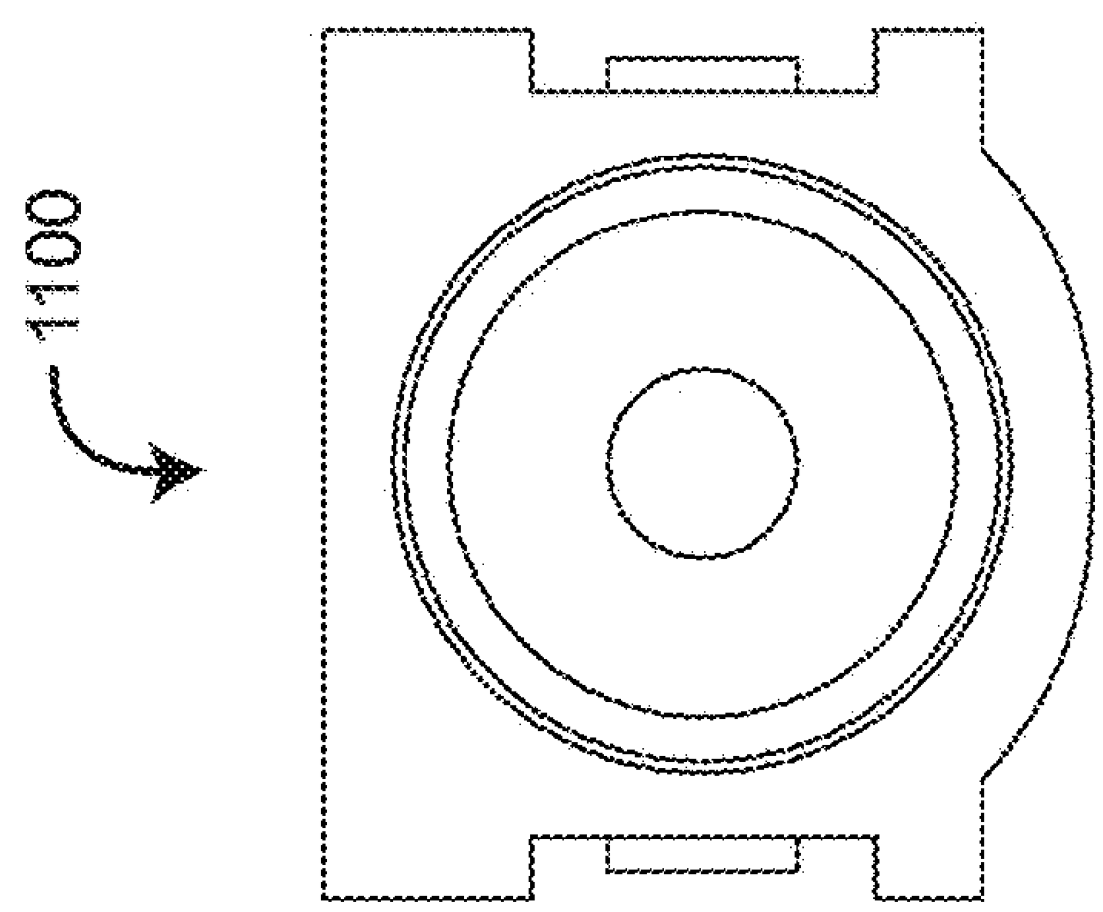

FIG. 11D

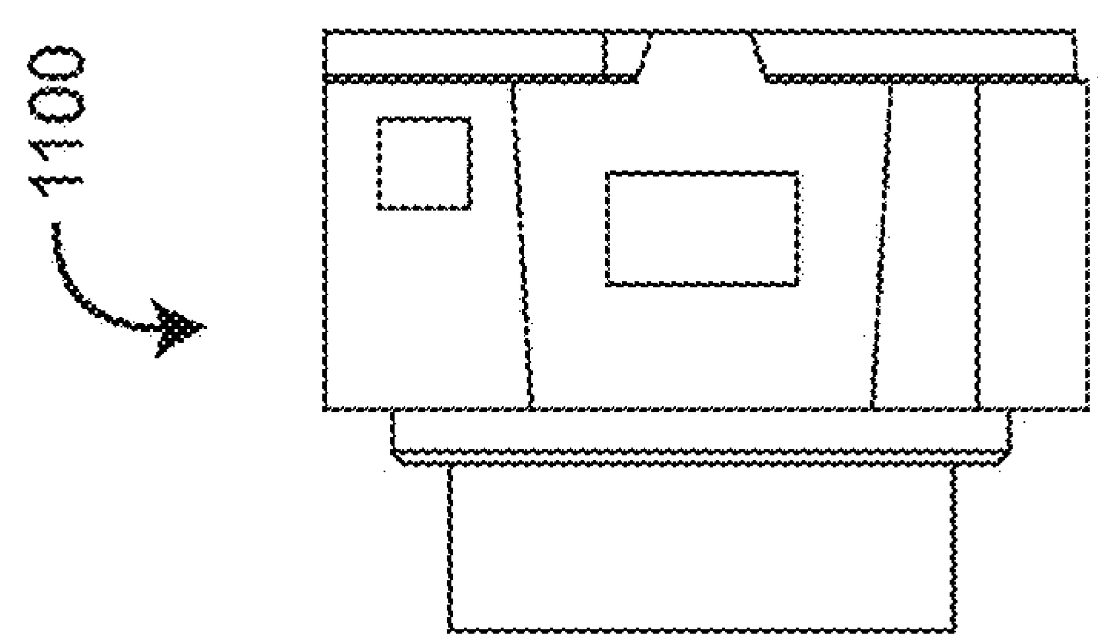

FIG. 11E

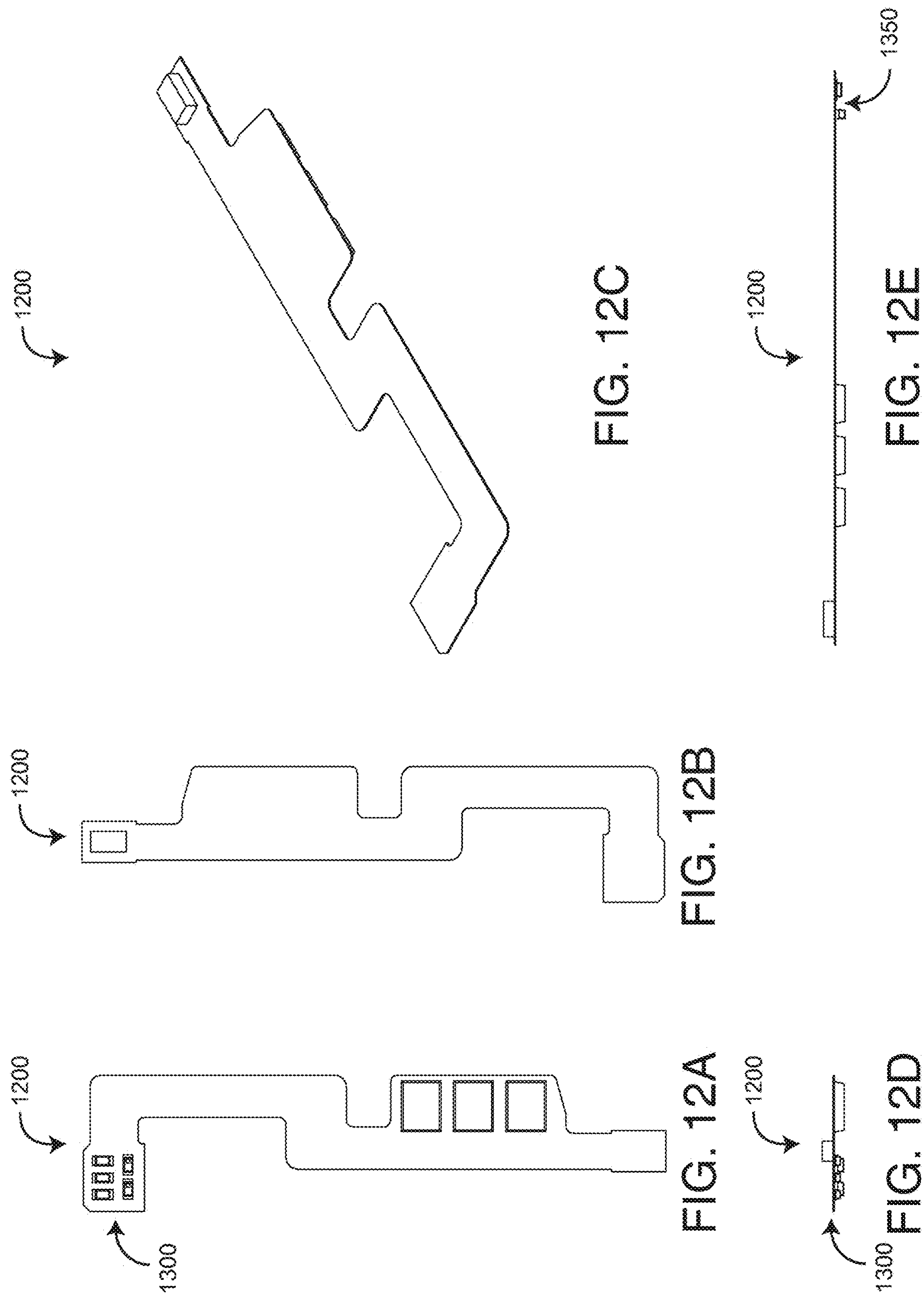

FIG. 12A

FIG. 12B

FIG. 12C

FIG. 12D

FIG. 12E

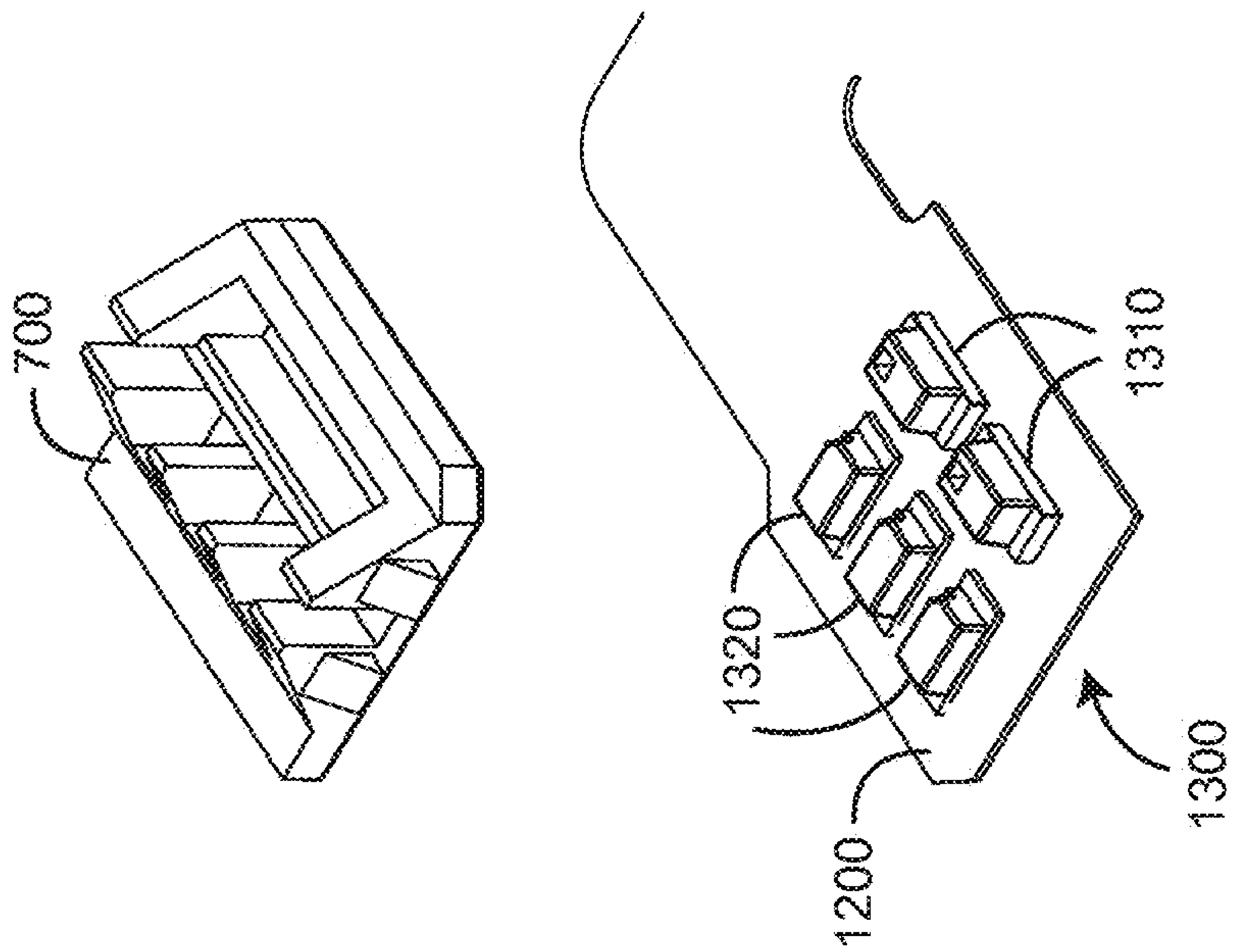

FIG. 13B

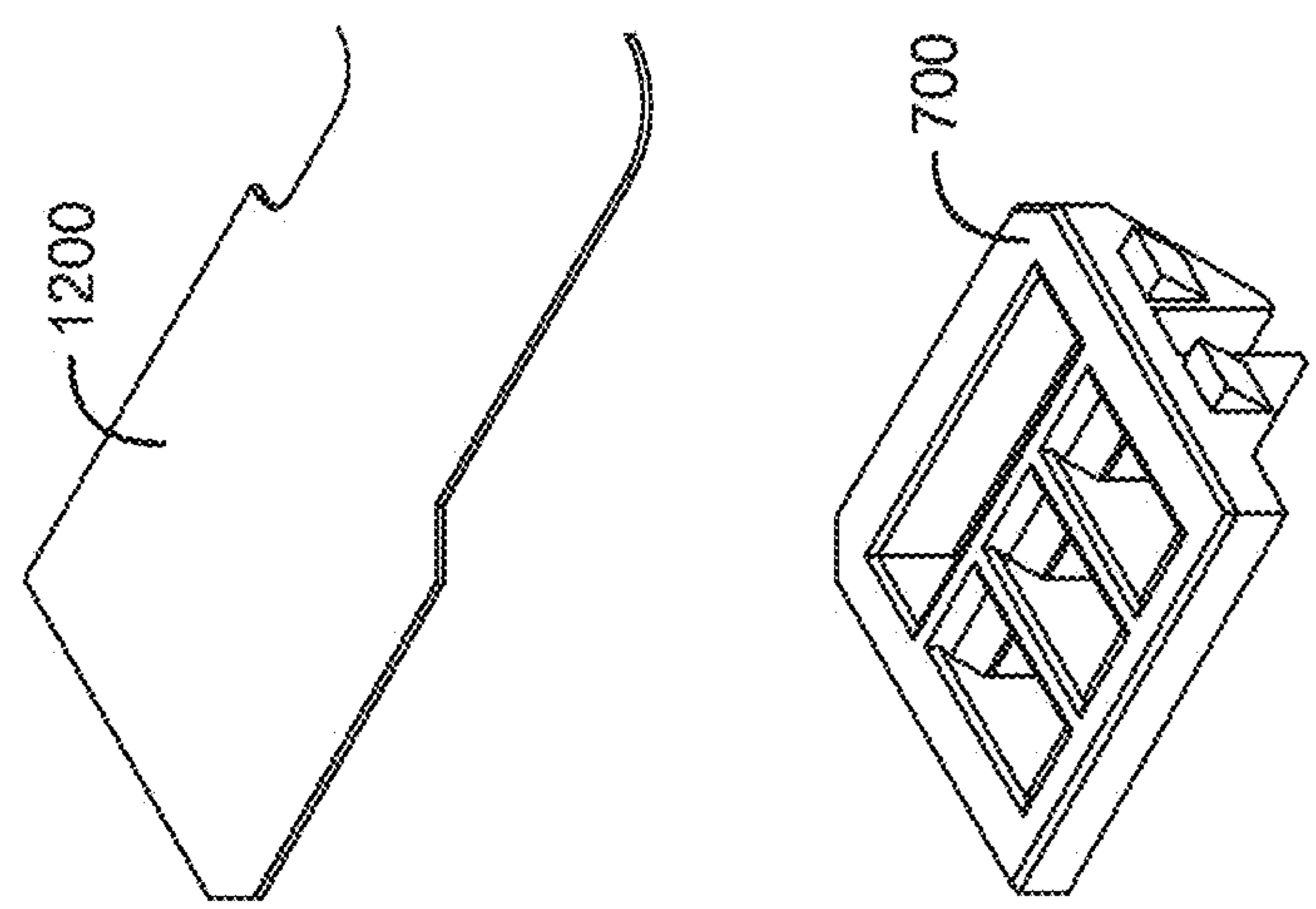

FIG. 13A

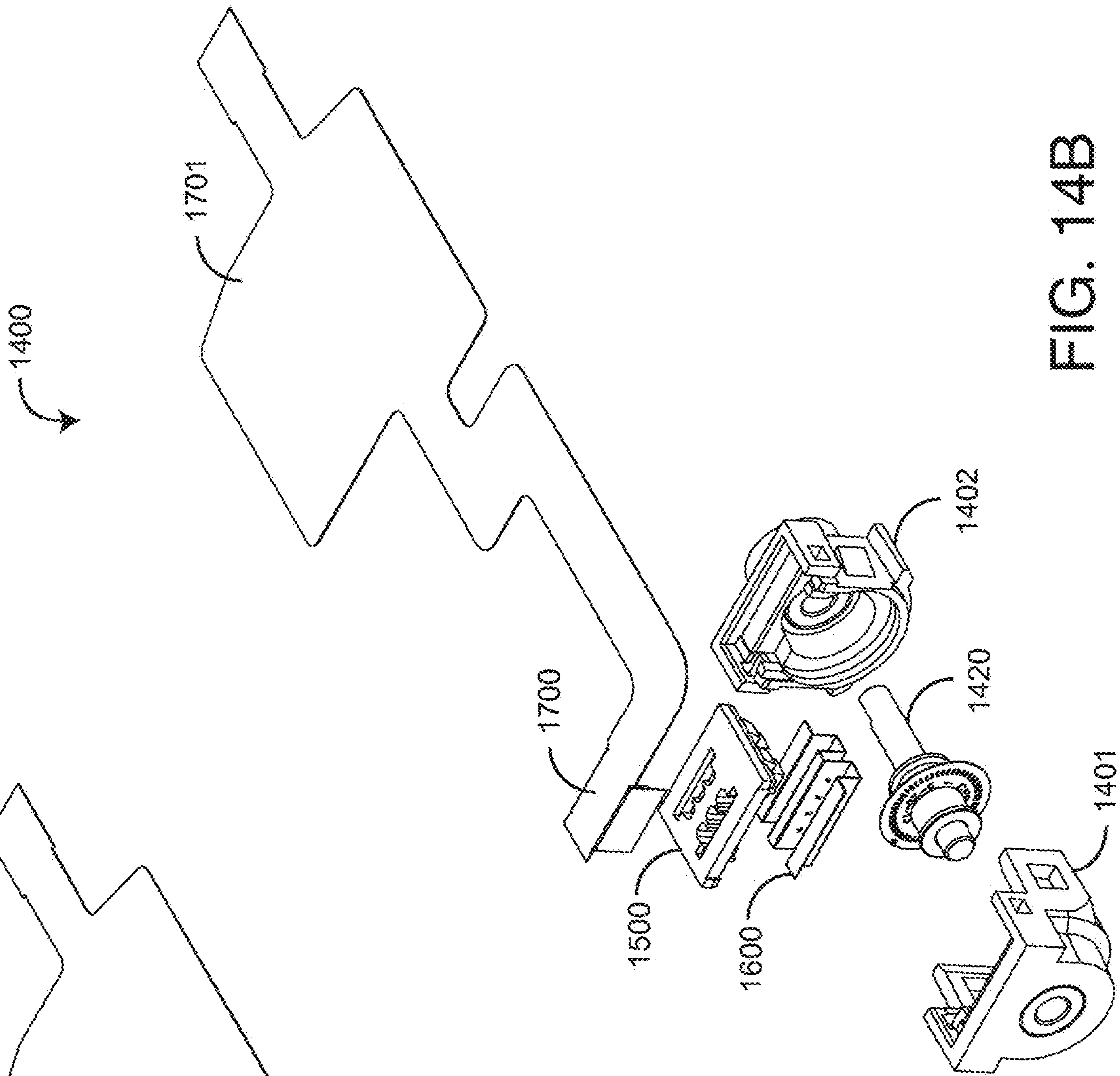

FIG. 14B

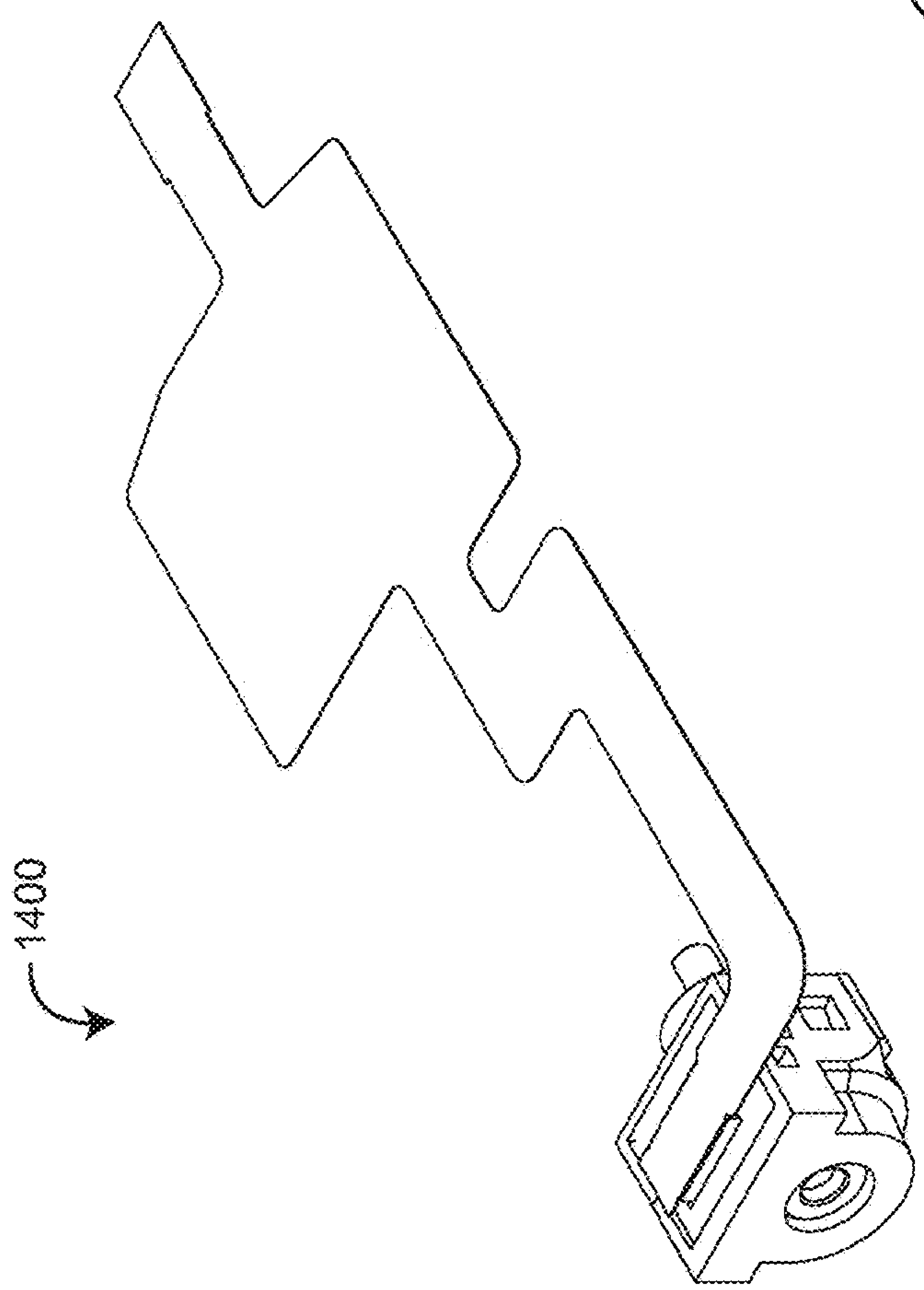

FIG. 14A

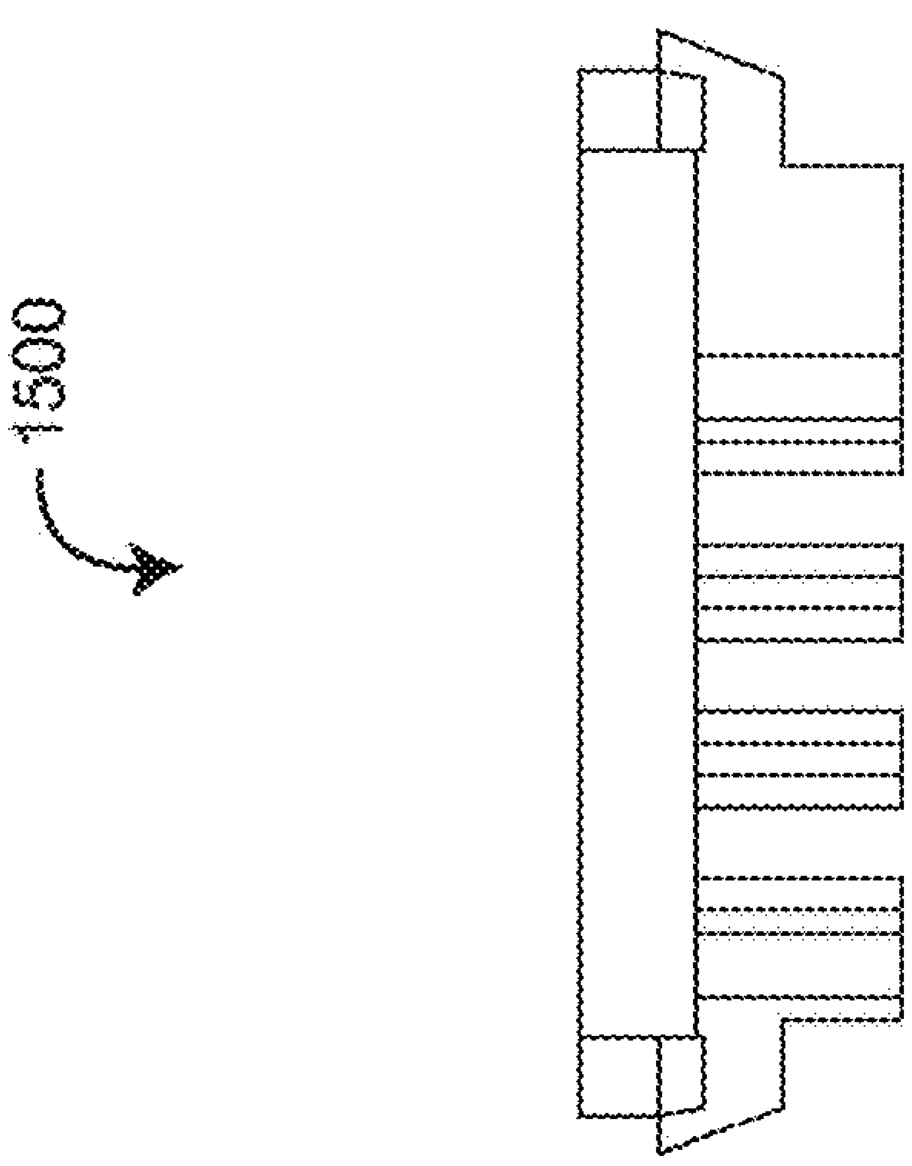

FIG. 15A

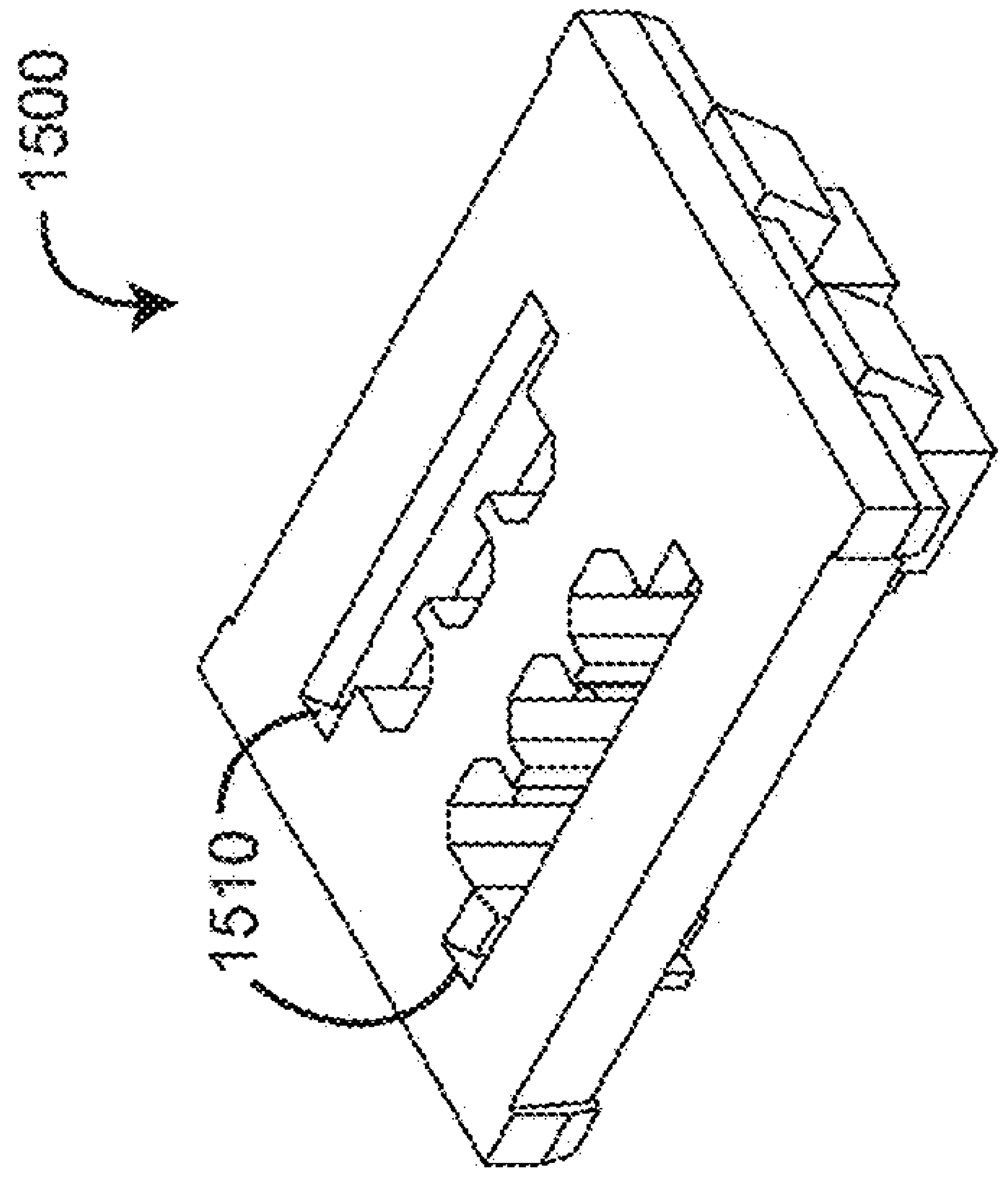

FIG. 15B

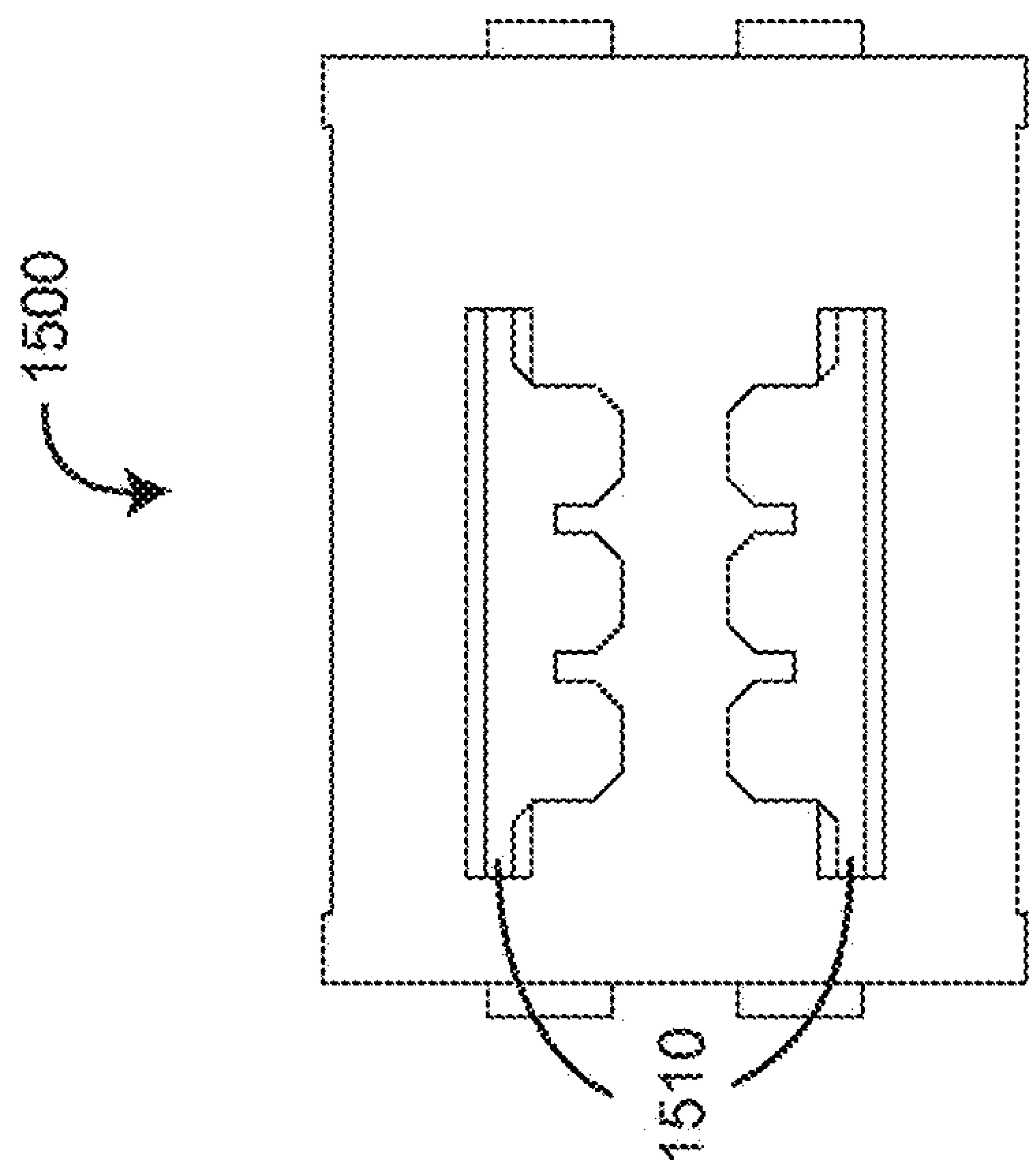

FIG. 15C

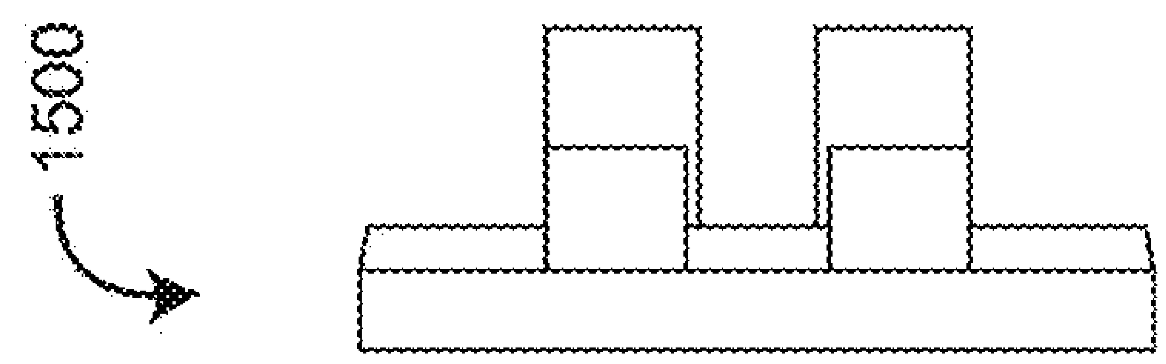

FIG. 15D

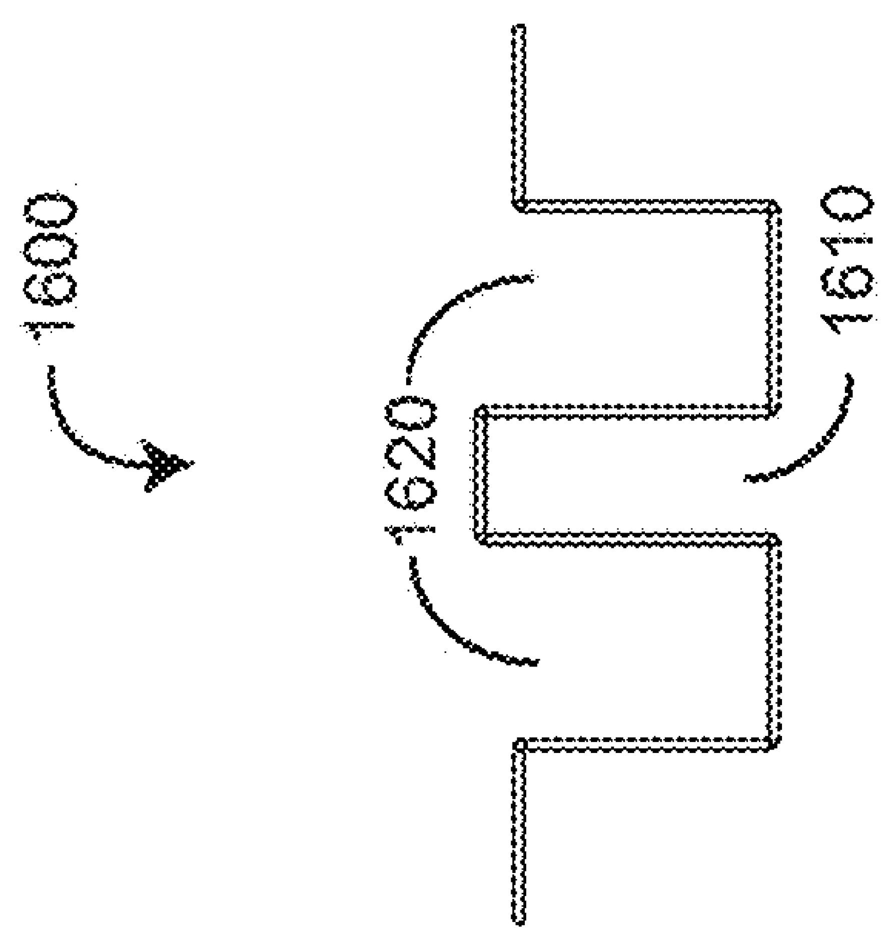

FIG. 16A

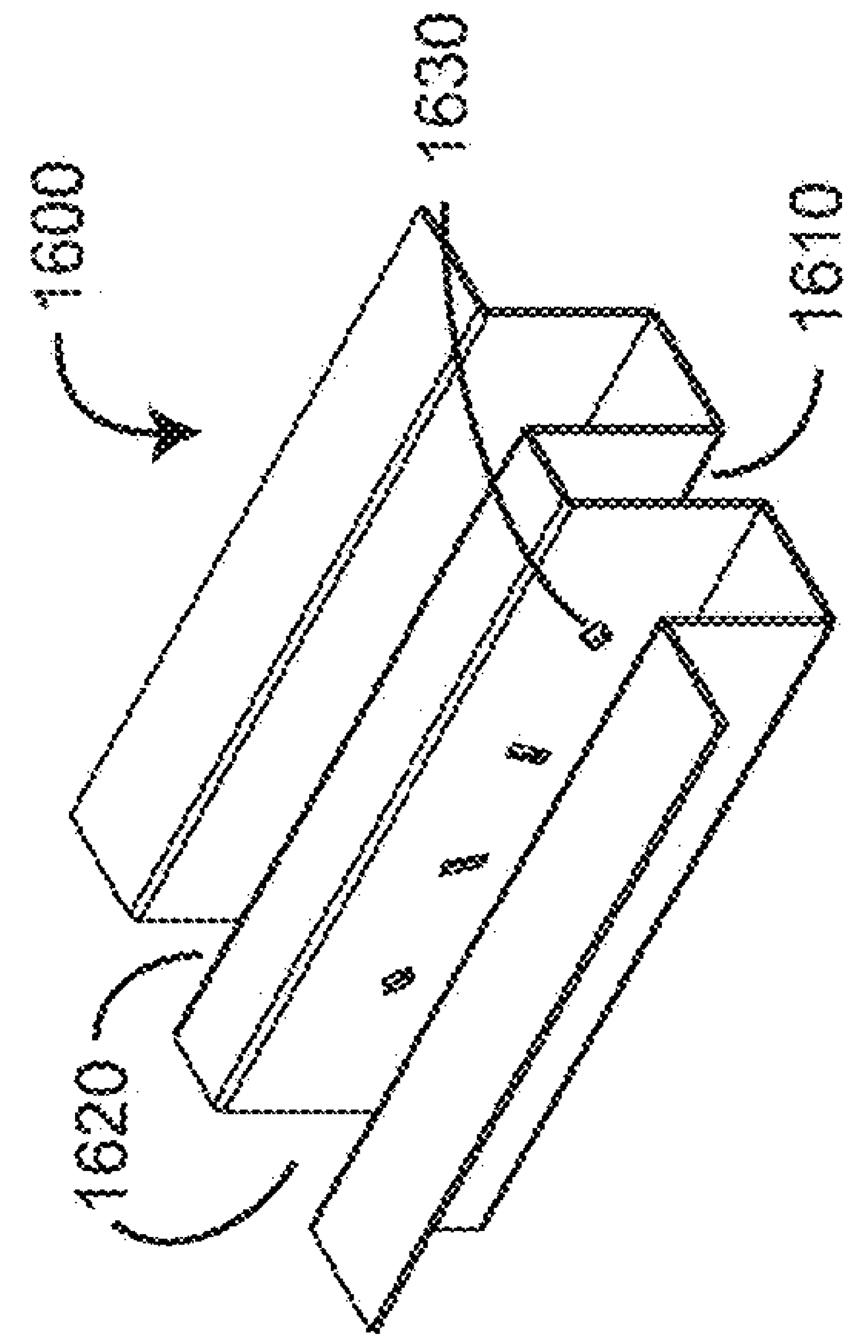

FIG. 16B

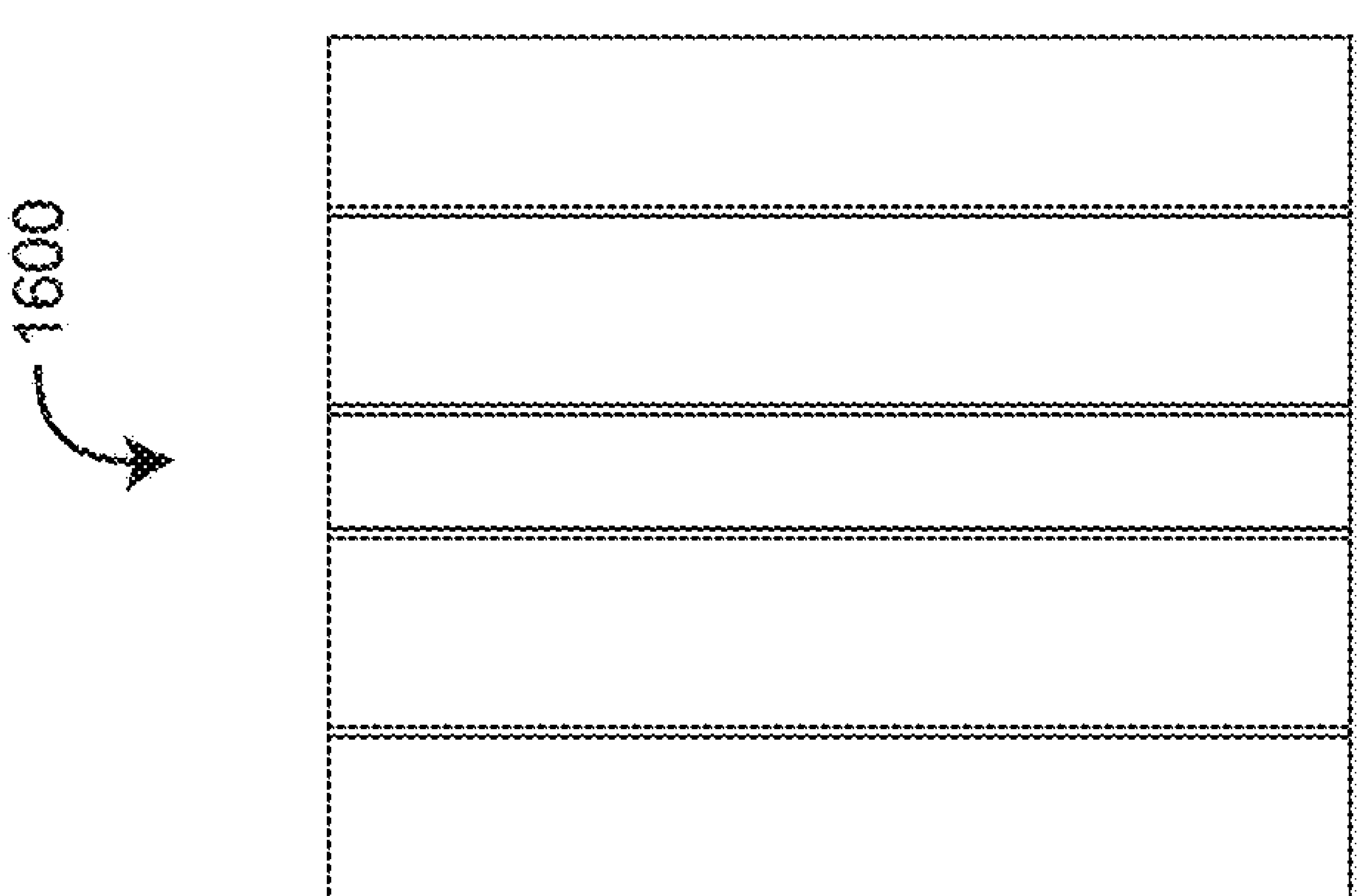

FIG. 16C

FIG. 16D

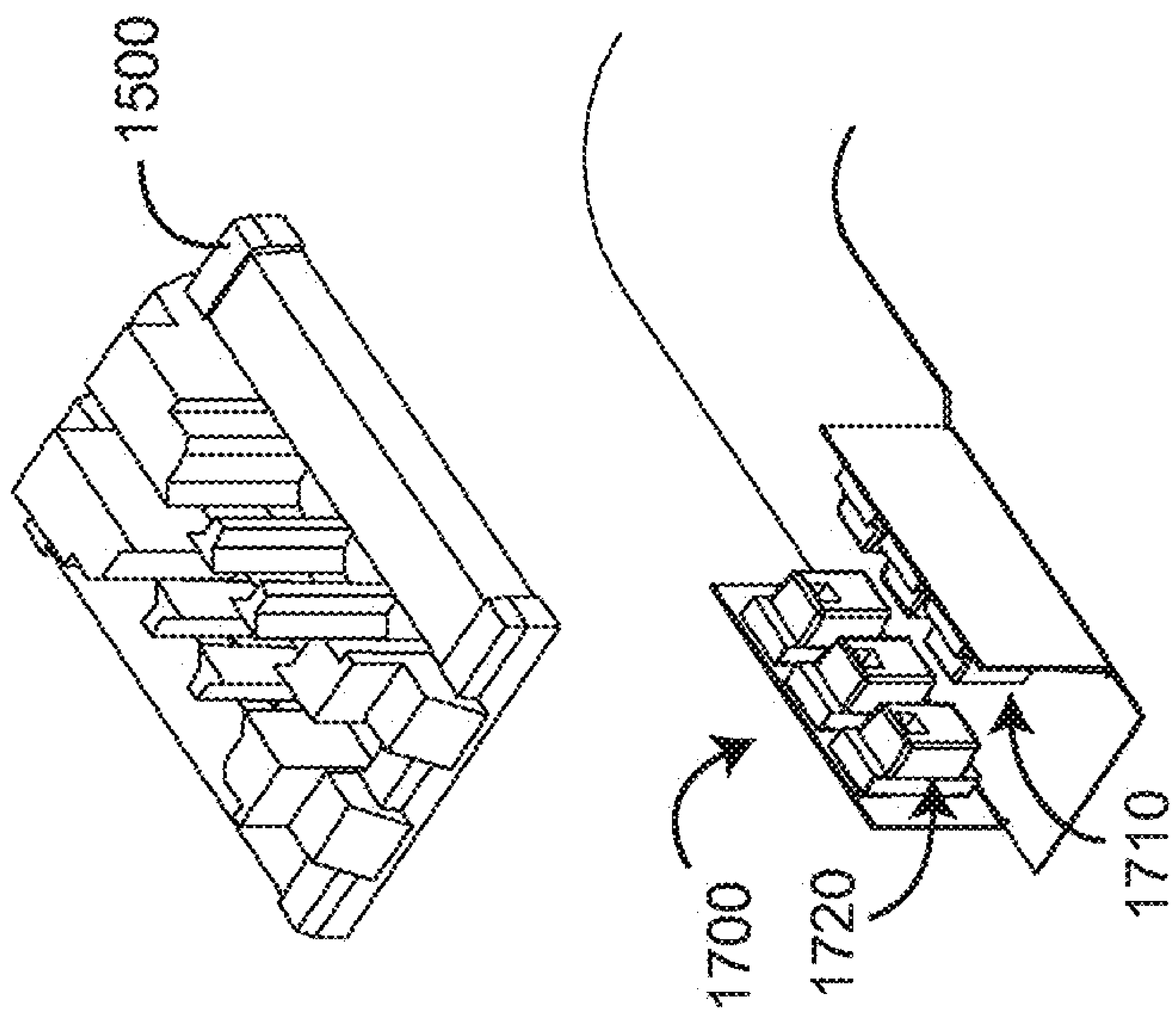

FIG. 17B

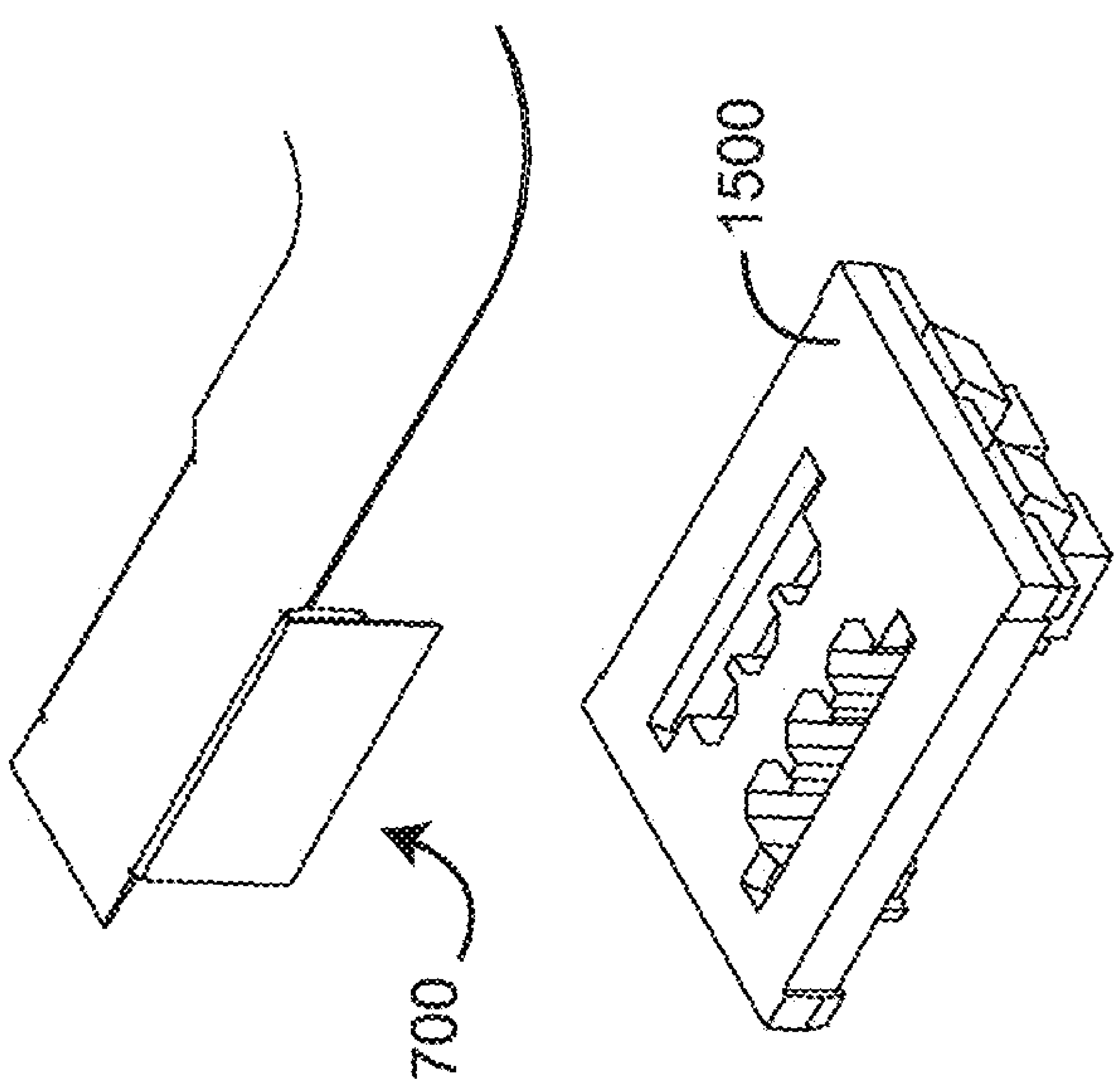

FIG. 17A

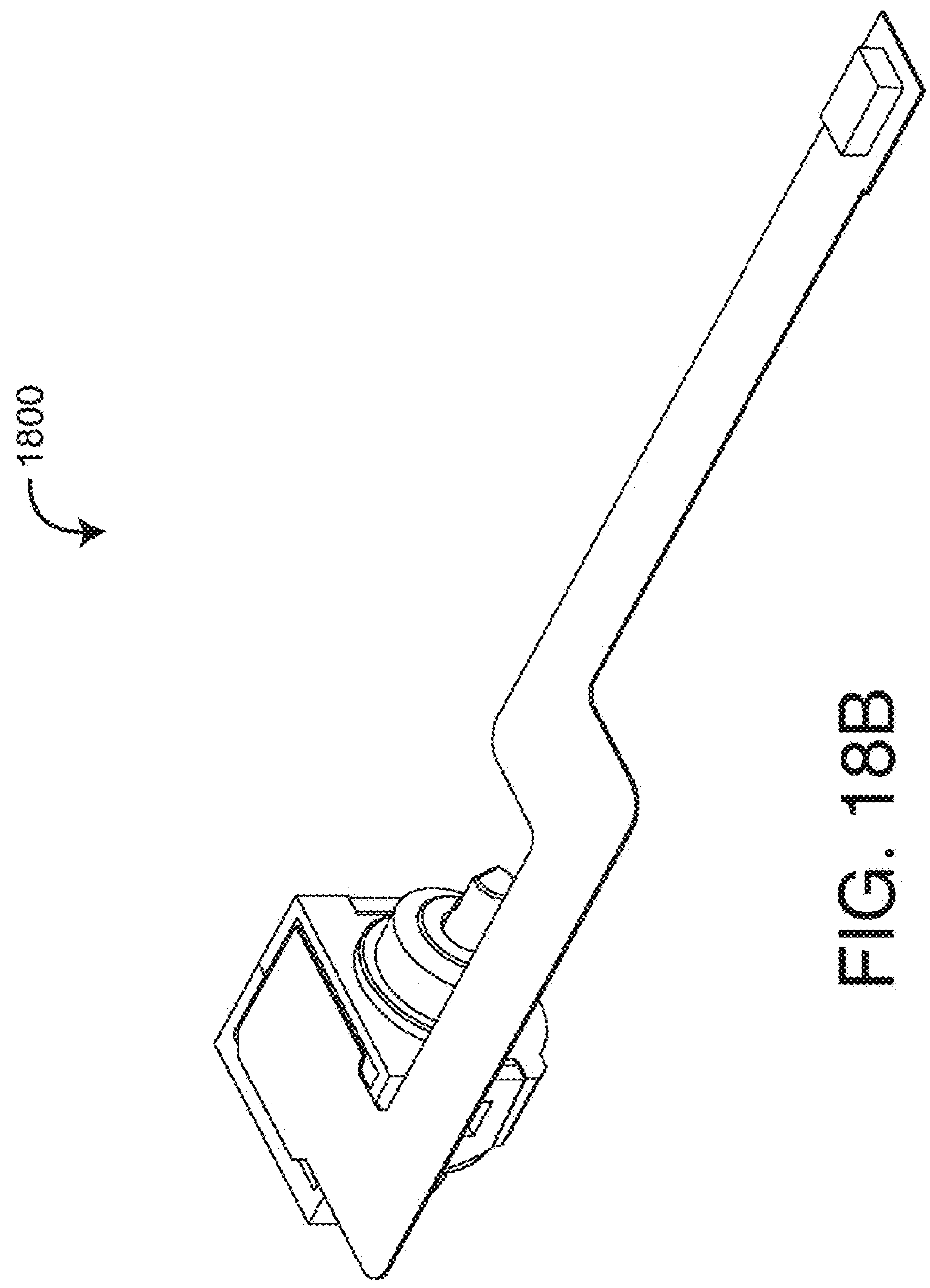

FIG. 18B

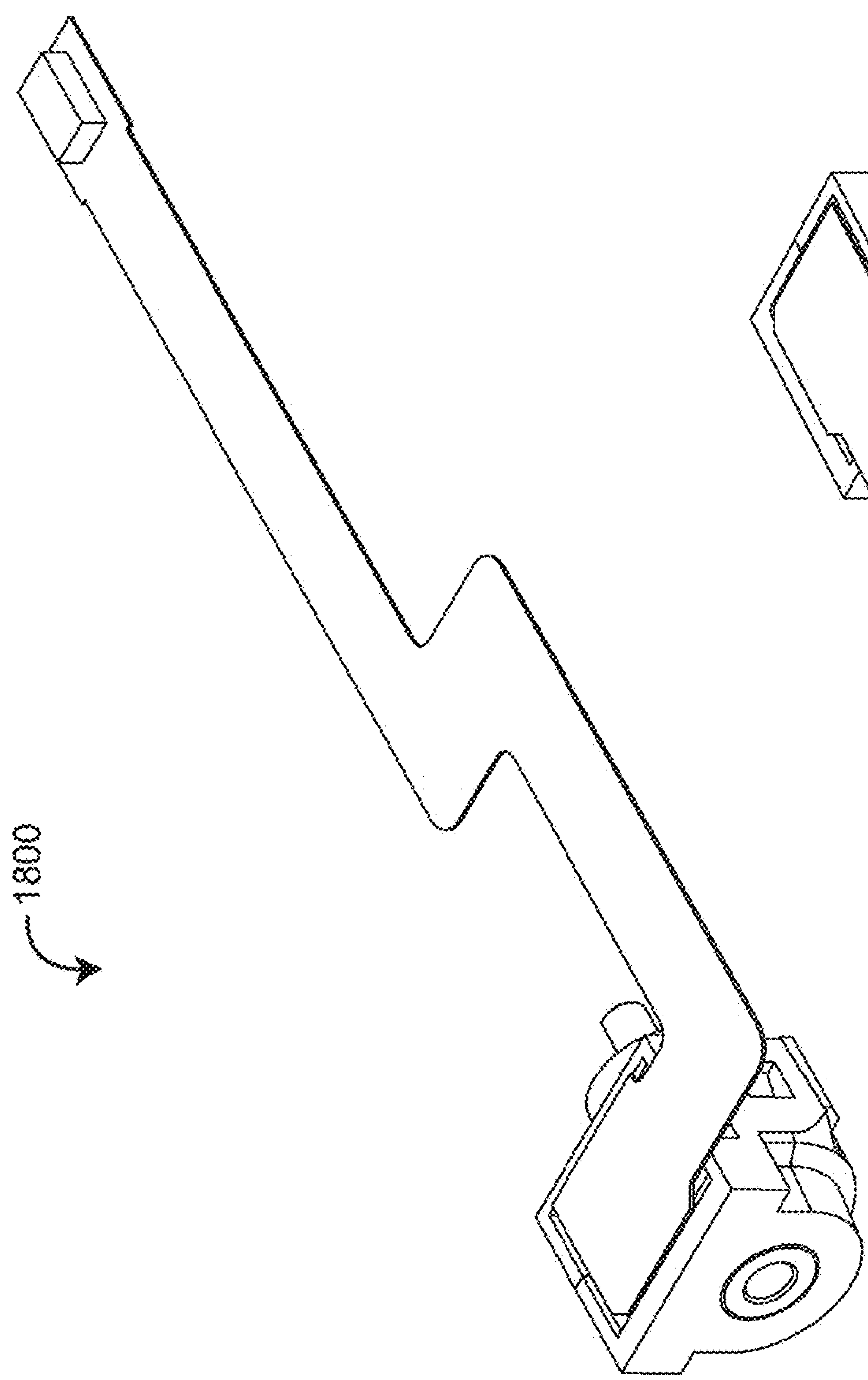

FIG. 18A

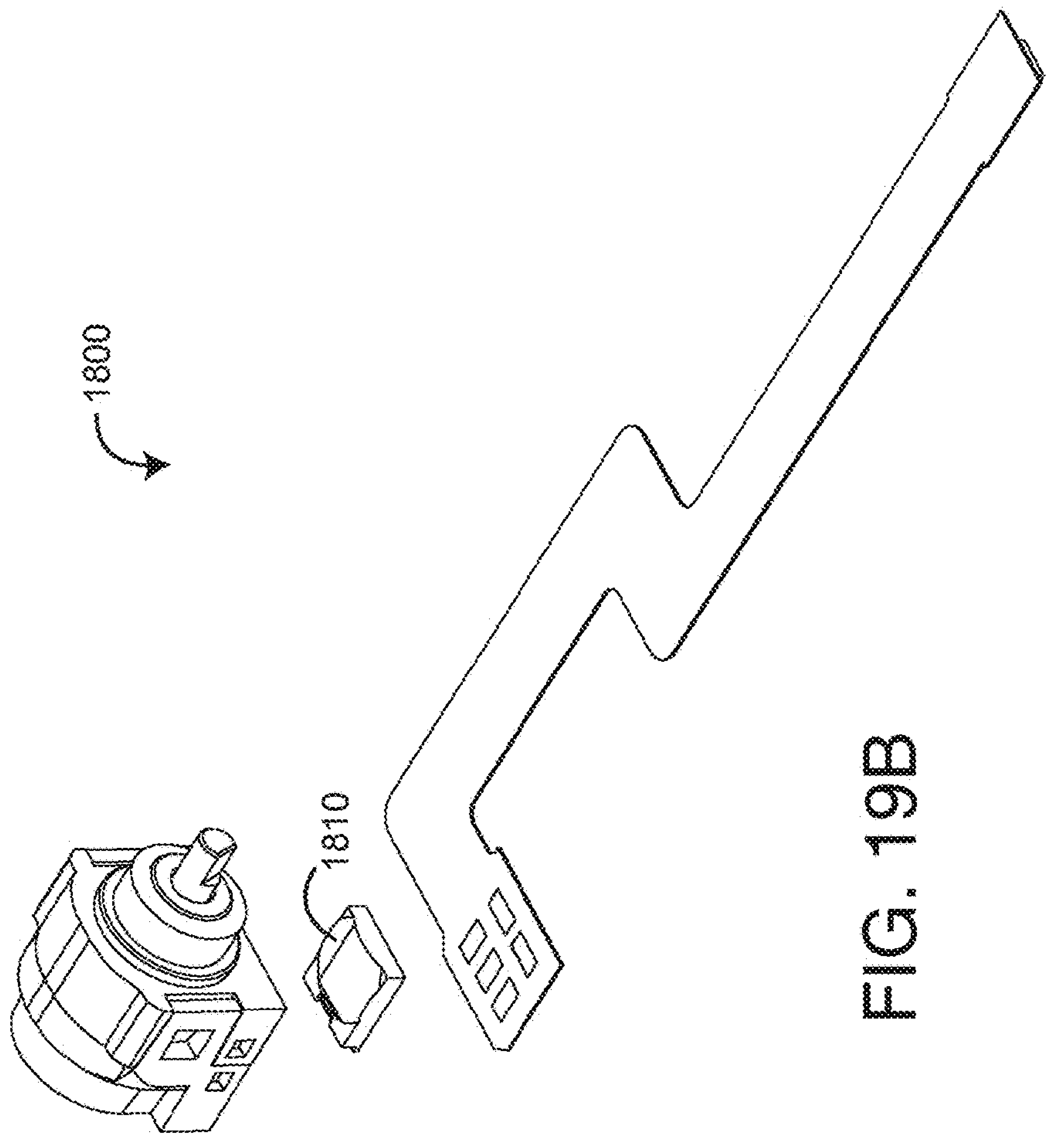

FIG. 19B

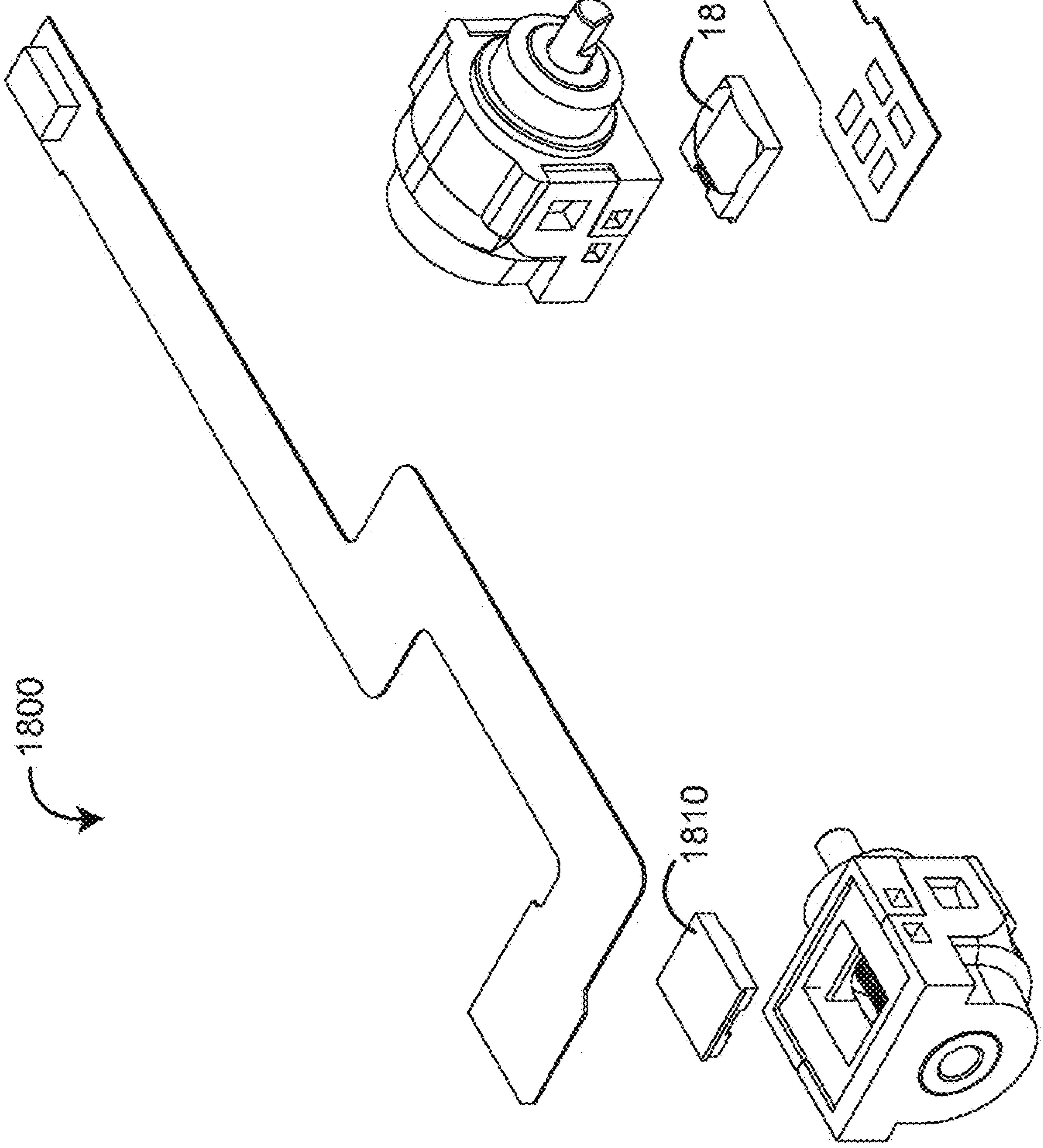

FIG. 19A

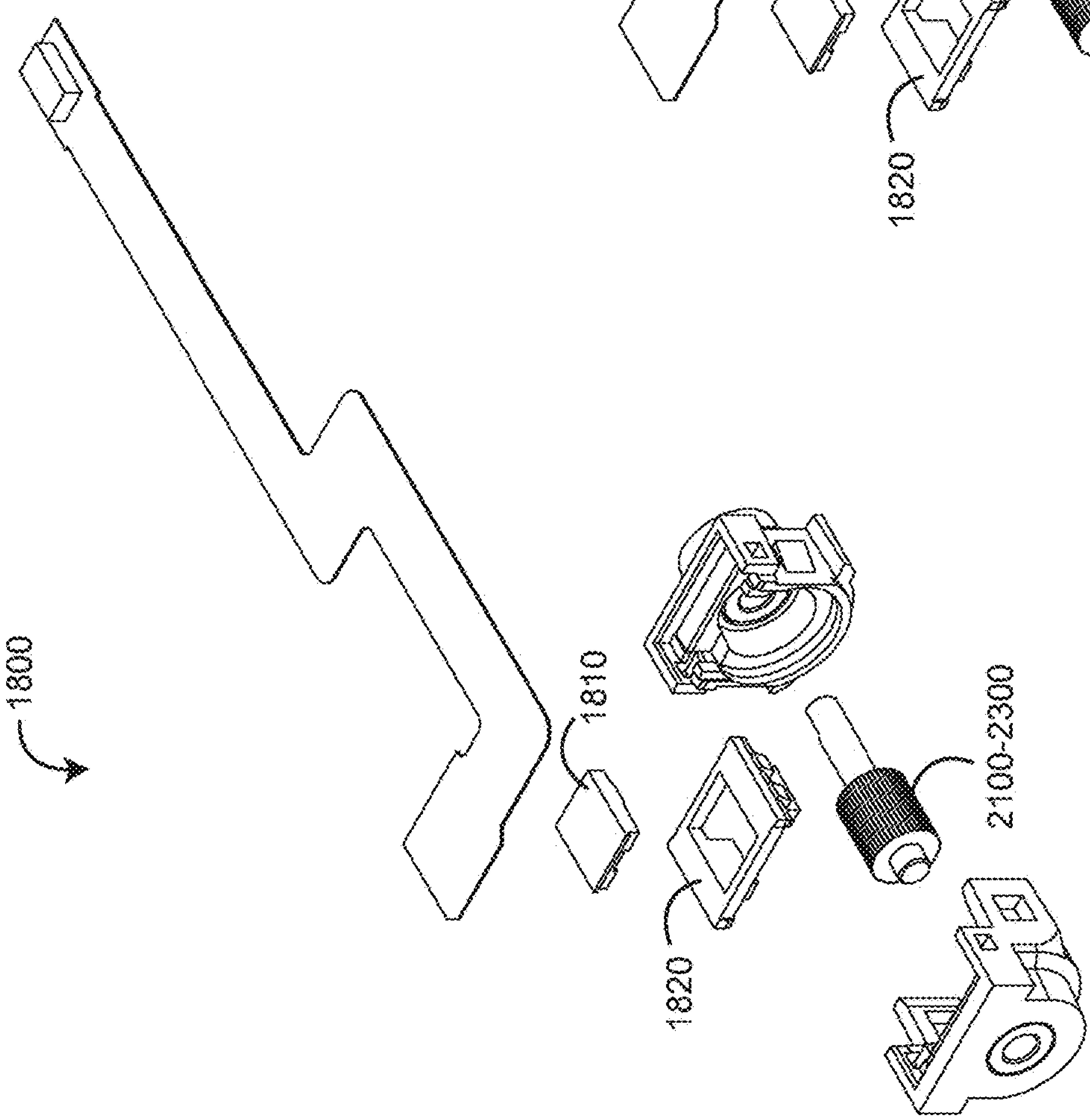

FIG. 20A

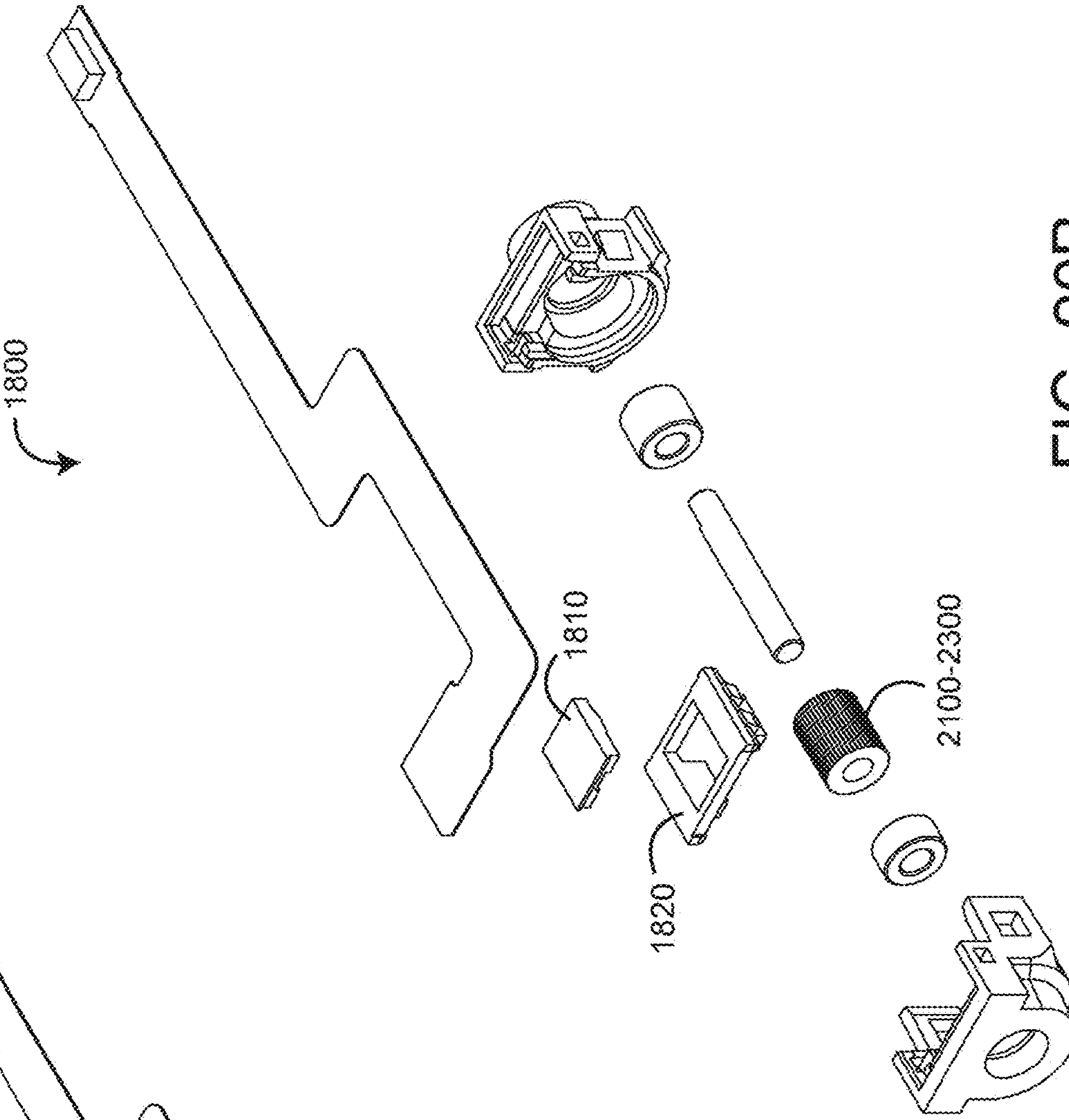

FIG. 20B

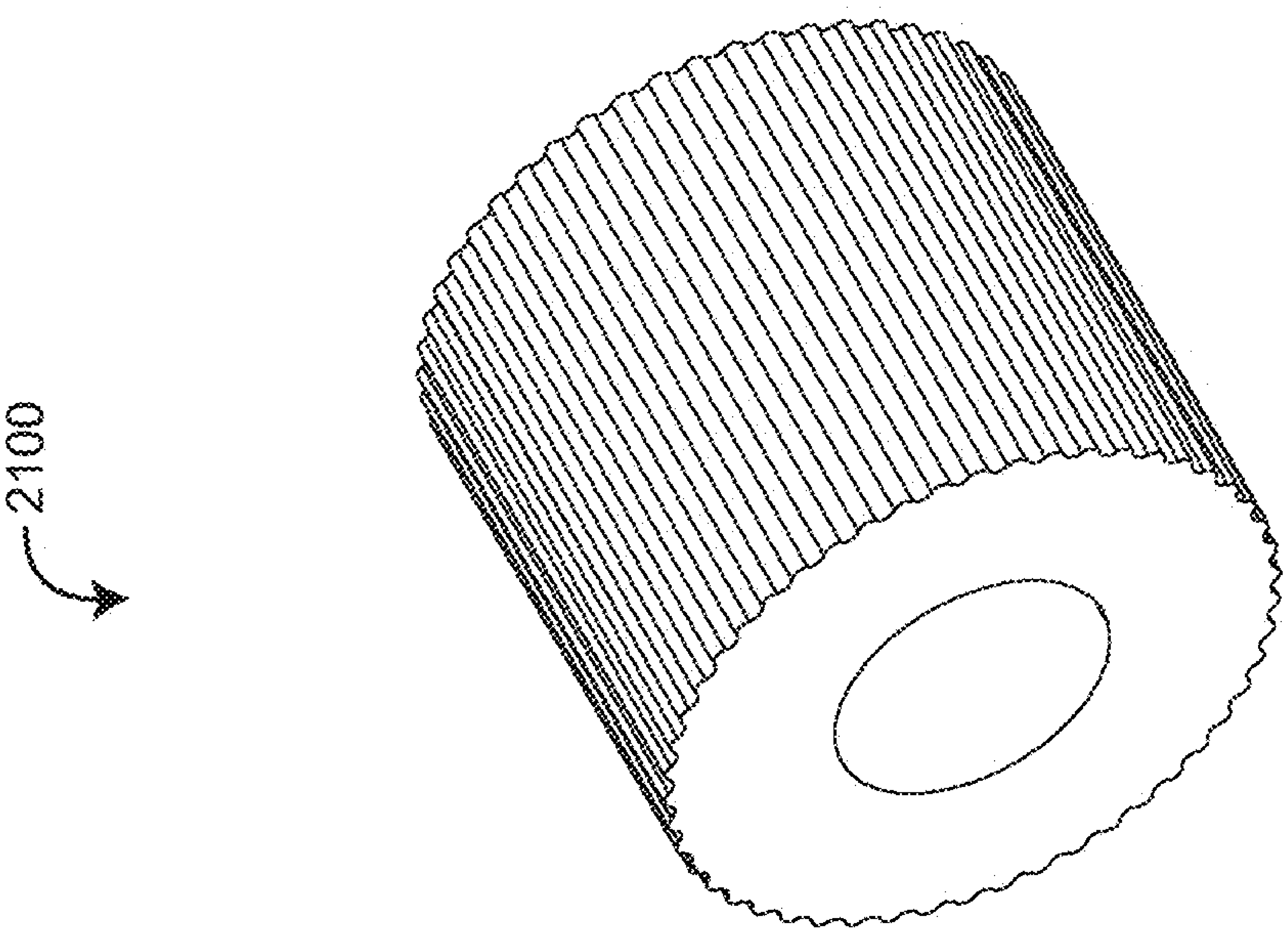

FIG. 21B

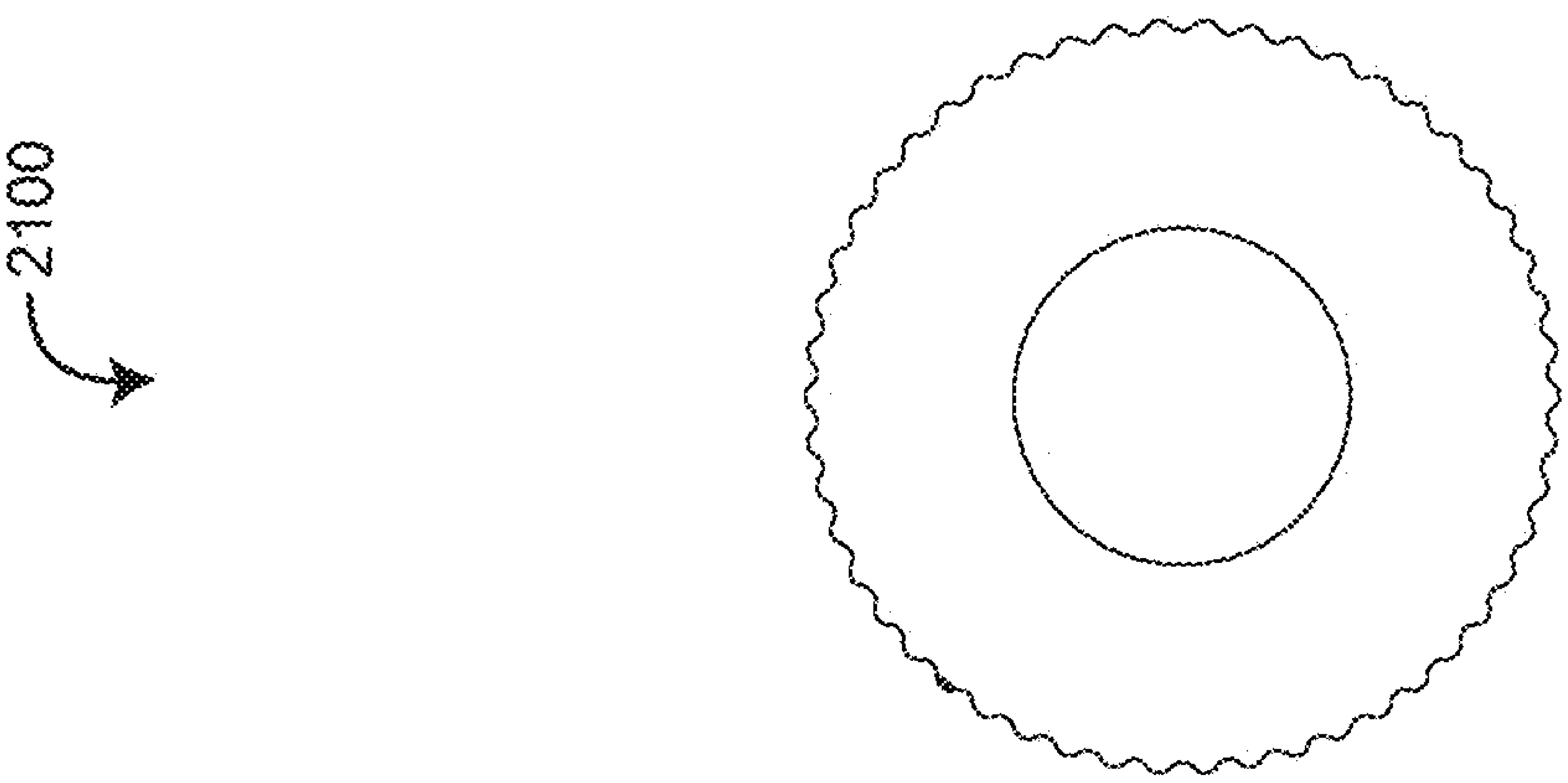

FIG. 21A

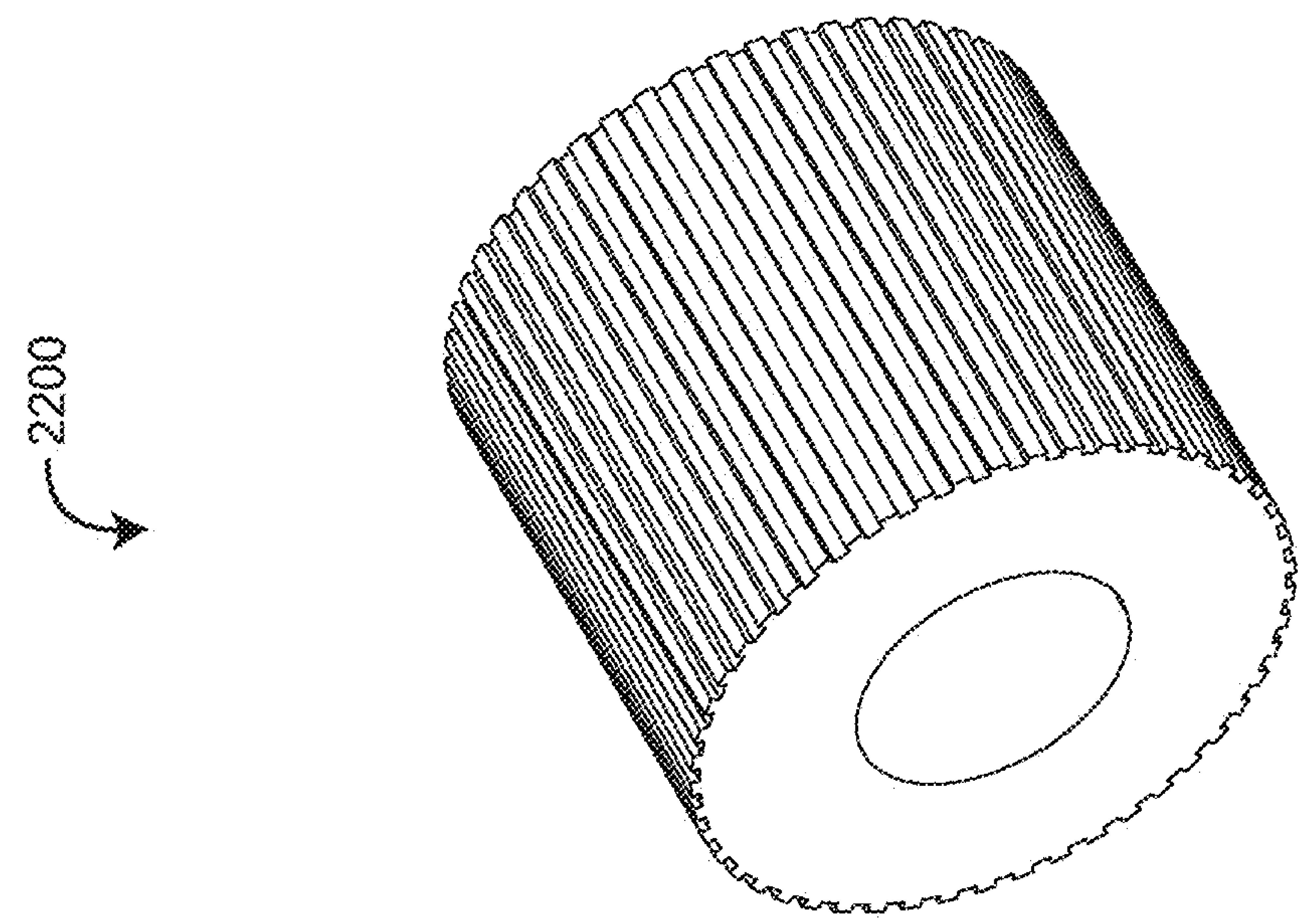

FIG. 22B

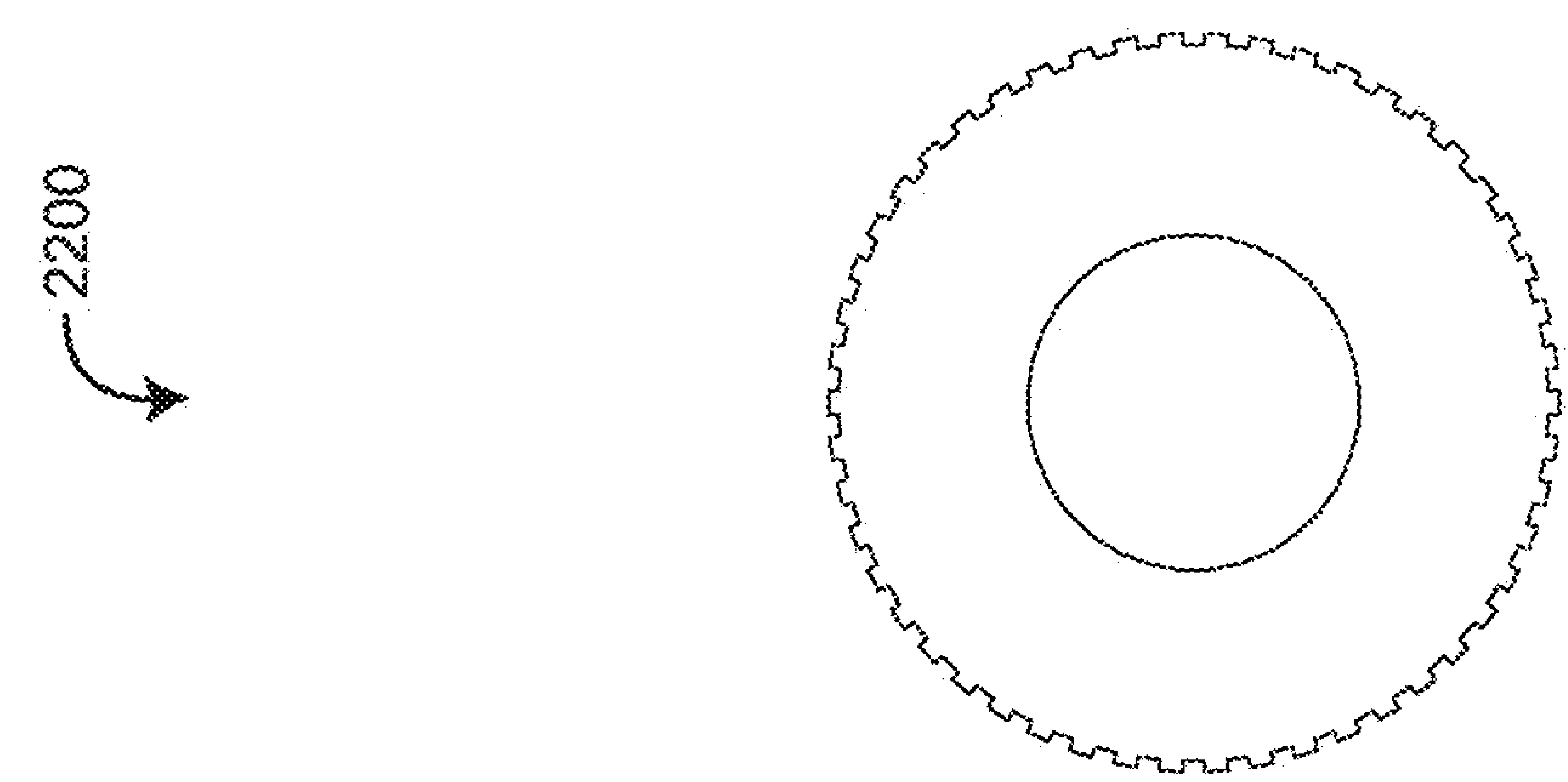

FIG. 22A

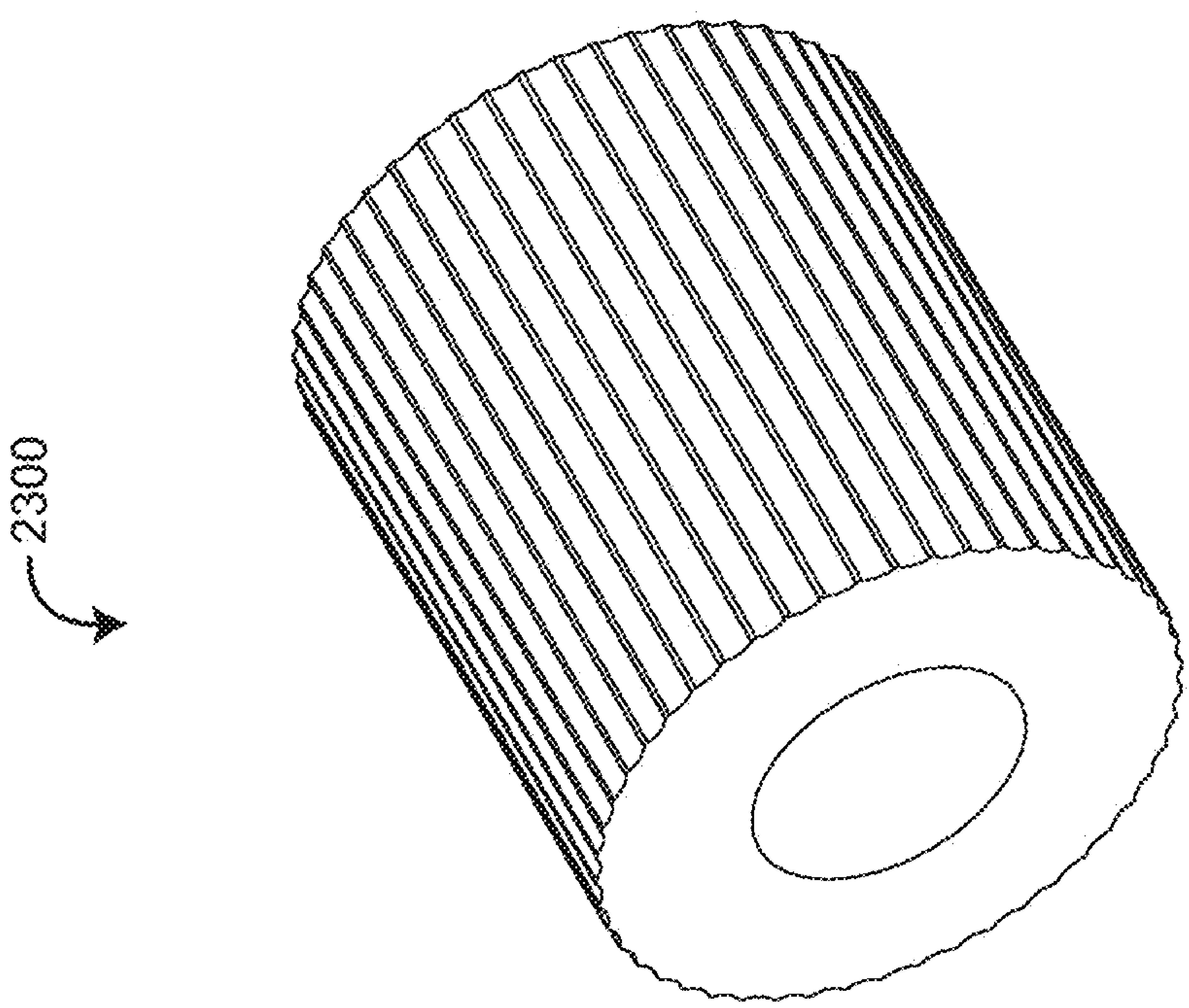

FIG. 23B

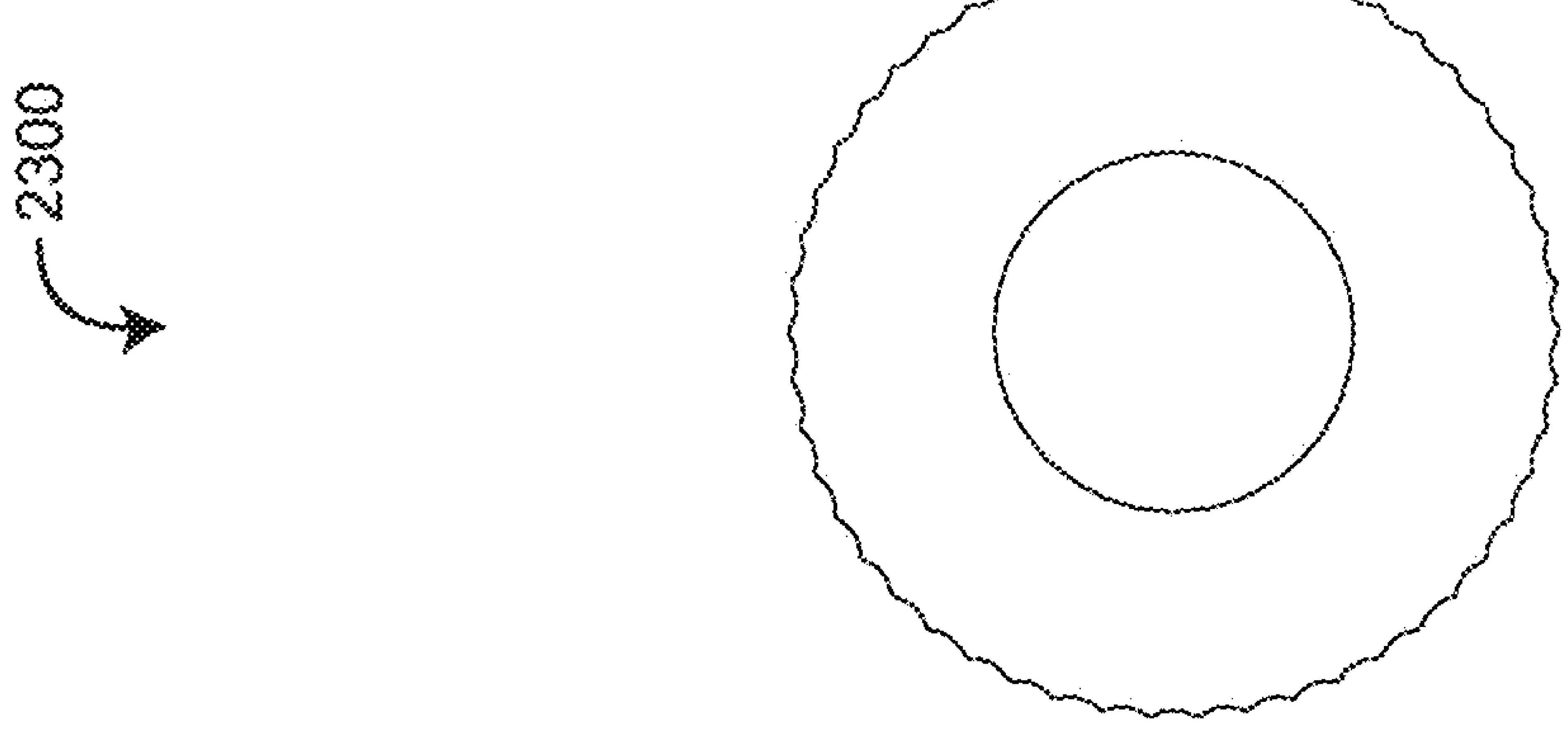

FIG. 23A

PULSER WITH DOUBLE-BEARING POSITION ENCODER FOR NON-INVASIVE PHYSIOLOGICAL MONITORING

PRIORITY CLAIM AND REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/334,662, filed on Jul. 17, 2014, entitled "DOUBLE-BEARING POSITION ENCODER FOR NON-INVASIVE PHYSIOLOGICAL MONITORING," which claims priority to U.S. Provisional Patent Application No. 61/847,307, filed Jul. 17, 2013, entitled "DOUBLE-BEARING POSITION ENCODER," the disclosures of all of which are incorporated in their entireties for all purposes.

BACKGROUND OF THE INVENTION

Noninvasive physiological monitoring systems for measuring constituents of circulating blood have advanced from basic pulse oximeters to monitors capable of measuring abnormal and total hemoglobin among other parameters. A basic pulse oximeter capable of measuring blood oxygen saturation typically includes an optical sensor, a monitor for processing sensor signals and displaying results and a cable electrically interconnecting the sensor and the monitor. A pulse oximetry sensor typically has a red wavelength light emitting diode (LED), an infrared (IR) wavelength LED and a photodiode detector. The LEDs and detector are attached to a patient tissue site, such as a finger. The cable transmits drive signals from the monitor to the LEDs, and the LEDs respond to the drive signals to transmit light into the tissue site. The detector generates a photoplethysmograph signal responsive to the emitted light after attenuation by pulsatile blood flow within the tissue site. The cable transmits the detector signal to the monitor, which processes the signal to provide a numerical readout of oxygen saturation (SpO_2) and pulse rate, along with an audible pulse indication of the person's pulse. The photoplethysmograph waveform may also be displayed.

Conventional pulse oximetry assumes that arterial blood is the only pulsatile blood flow in the measurement site. During patient motion, venous blood also moves, which causes errors in conventional pulse oximetry. Advanced pulse oximetry processes the venous blood signal so as to report true arterial oxygen saturation and pulse rate under conditions of patient movement. Advanced pulse oximetry also functions under conditions of low perfusion (small signal amplitude), intense ambient light (artificial or sunlight) and electrosurgical instrument interference, which are scenarios where conventional pulse oximetry tends to fail.

Advanced pulse oximetry is described in at least U.S. Pat. Nos. 6,770,028; 6,658,276; 6,157,850; 6,002,952; 5,769,785 and 5,758,644, which are assigned to Masimo Corporation ("Masimo") of Irvine, Calif. and are incorporated in their entireties by reference herein. Corresponding low noise optical sensors are disclosed in at least U.S. Pat. Nos. 6,985,764; 6,813,511; 6,792,300; 6,256,523; 6,088,607; 5,782,757 and 5,638,818, which are also assigned to Masimo and are also incorporated in their entireties by reference herein. Advanced pulse oximetry systems including Masimo SET® low noise optical sensors and read through motion pulse oximetry monitors for measuring SpO_2, pulse rate (PR) and perfusion index (PI) are available from Masimo. Optical sensors include any of Masimo LNCS®, SofTouch™ and Blue™ adhesive or reusable sensors. Pulse oximetry monitors include any of Masimo Rad-8®, Rad-5®, Rad®-5v or SatShare® monitors.

Advanced blood parameter measurement systems are described in at least U.S. Pat. No. 7,647,083, filed Mar. 1, 2006, titled Multiple Wavelength Sensor Equalization; U.S. Pat. No. 7,729,733, filed Mar. 1, 2006, titled Configurable Physiological Measurement System; U.S. Pat. Pub. No. 2006/0211925, filed Mar. 1, 2006, titled Physiological Parameter Confidence Measure and U.S. Pat. Pub. No. 2006/0238358, filed Mar. 1, 2006, titled Noninvasive Multi-Parameter Patient Monitor, all assigned to Cercacor Laboratories, Inc., Irvine, Calif. ("Cercacor") and all incorporated in their entireties by reference herein. An advanced parameter measurement system that includes acoustic monitoring is described in U.S. Pat. Pub. No. 2010/0274099, filed Dec. 21, 2009, titled Acoustic Sensor Assembly, assigned to Masimo and incorporated in its entirety by reference herein.

Advanced blood parameter measurement systems include Masimo Rainbow® SET, which provides measurements in addition to SpO_2, such as total hemoglobin (SpHb™), oxygen content (SpOC™) methemoglobin (SpMet®), carboxyhemoglobin (SpCO®) and PVI®. Advanced blood parameter sensors include Masimo Rainbow® adhesive, ReSposable™ and reusable sensors. Advanced blood parameter monitors include Masimo Radical-7™, Rad-87™ and Rad-57™ monitors, all available from Masimo. Advanced parameter measurement systems may also include acoustic monitoring such as acoustic respiration rate (RRa™) using a Rainbow Acoustic Sensor™ and Rad-87™ monitor, available from Masimo. Such advanced pulse oximeters, low noise sensors and advanced parameter systems have gained rapid acceptance in a wide variety of medical applications, including surgical wards, intensive care and neonatal units, general wards, home care, physical training, and virtually all types of monitoring scenarios.

FIG. **1** illustrates an active pulse generator **100** that installs within a reusable optical sensor for precisely pulsing a tissue site, such a fingertip. The active pulse generator **100** has a motor **110**, a cam **120**, a housing **130**, a pulser **140** and an optical encoder **200**. The cam **120** and pulser **140** are located within the housing **130**. A shaft **160** couples the motor **110** to the cam **120** so as to linearly-actuate the pulser **140** upon application of electric current to the motor **110**. The encoder **200** extends into the housing **130** so as to mechanically couple to the cam **120**. The encoder **200** measures the rotation of the cam **120** and hence the position of the pulser **140**. Based upon encoder feedback, the pulser **140** frequency and phase, and hence that of an active pulse, can be accurately measured and controlled. An active pulse reusable optical sensor is described in U.S. patent application Ser. No. 13/473,477, titled Personal Health Device, filed May 16, 2012 and assigned to Cercacor is hereby incorporated in its entirety by reference herein.

FIG. **2** further illustrates the encoder **200**, which has a housing **210**, a single-bearing **220** that mounts an encoder axle **230** to an encoder wheel **240** and an optics assembly that senses reflective position tracks and an index track on the encoder wheel **240** so as to generate a two-channel quadrature square wave output indicative of the axle **230** position.

SUMMARY OF THE INVENTION

A single-bearing encoder wheel mount, as described with respect to FIG. **2**, above, has insufficient mechanical stability to provide optimum accuracy in measuring and controlling the phase and frequency of an optical sensor active pulse.

Double-bearing position encoder embodiments advantageously improve encoder wheel stability so as to improve active pulse accuracy and also solve encoder wheel/optical reader configuration issues created by the necessary location of the stabilizing second bearing.

One aspect of a double-bearing position encoder is a housing, a pair of bearings disposed within opposite facing walls of the housing and an axle disposed within the housing and supported by the bearings. The axle is in mechanical communications with a pulser. An encoder wheel having wheel slots is fixedly attached to the axle. An LED is disposed within the housing so as to illuminate the encoder wheel. A detector is responsive to the LED illumination after optical interaction with the wheel slots as the axle rotates the wheel so as to indicate the wheel position.

In an embodiment, the axle is stabilized within a housing via bearings disposed on opposite walls of the housing. The axle is in communications with a rotating cam that actuates a pulser so as to generate an active pulse at a tissue site for analysis by an optical sensor. The axle rotates a slotted encoder wheel or a reflective encoder cylinder so as to accurately determine the axle position and, hence, the active pulse frequency and phase.

In various embodiment, the encoder comprises an encoder mask having mask slots disposed over an edge and along both sides of the encoder wheel so that the LED illumination passes through the mask slots and the wheel slots before reaching the detector. The encoder mask is folded so that LED light is reflected off of the mask a first time before illuminating the encoder wheel and second time before reaching the detector. Alternatively, the encoder mask is folded so that LED light is not reflected off of the mask before illuminating the encoder wheel and before reaching the detector.

Another aspect of a double-bearing position encoder is a rotatable axle. An encoder wheel is rotatably mounted on the double-bearing-mounted axle. An encoder mask is folded proximate an outer edge of the encoder wheel. Wheel slots are disposed around the encoder wheel proximate the outer edge. Mask slots are disposed through the encoder mask, and an emitter and a detector are disposed proximate to and on either side of the encoder wheel so that light intermittently passes through the encoder wheel via the wheel slots and the mask slots.

In various embodiments, light is reflected from the emitter off of the mask at least once before it reaches the detector. Light is reflected from the emitter off of the mask twice before it reaches the detector. The emitter directly illuminates the detector without reflection off the mask.

A further aspect of a double-bearing position encoder is a double bearing means of stabilizing a rotatable axle within an encoder housing. An encoder wheel means fixedly mounted to the axle so as to rotate as the axle rotates. An illumination and detection means of intermittently passing light through the encoder wheel means as it rotates, and a folded and slotted mask means of precisely passing light through encoder wheel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective illustration of an optical sensor active pulse generator including a single-bearing position encoder;

FIG. **2** is a cutaway side view of a single-bearing position encoder;

FIGS. **3**A-B are cutaway side views of double-bearing position encoder embodiments incorporating a slotted wheel encoder;

FIG. **4** is a cutaway side view of a double-bearing position encoder embodiment incorporating a reflective cylinder encoder;

FIGS. **5**A-B are front and back perspective views of a double-bearing position encoder assembly;

FIGS. **6**A-B are partially exploded and exploded perspective views, respectively, of a double-bearing position encoder assembly;

FIGS. **7**A-E are top, front, bottom, side and perspective views, respectively, of an encoder mask block;

FIGS. **8**A-D are top, perspective, front and side views, respectively, of an encoder mask;

FIGS. **9**A-D are top, perspective, front and side views, respectively, of a slotted encoder wheel;

FIGS. **10**A-E are top, perspective, front, back and side views, respectively, of an encoder front housing;

FIGS. **11**A-E are top, perspective, front, back and side views, respectively, of an encoder back housing;

FIGS. **12**A-E are top, bottom, perspective, front and side views, respectively, of an encoder flex circuit;

FIGS. **13**A-B are top and bottom exploded views, respectively, of flex circuit optics and a corresponding encoder mask block;

FIGS. **14**A-B are assembled and partially exploded perspective views, respectively, of another double-bearing position encoder assembly;

FIGS. **15**A-D are front, perspective, top and side views, respectively, of an encoder mask block;

FIGS. **16**A-D are front, perspective, top and side views, respectively, of an encoder mask;

FIGS. **17**A-B are top and bottom exploded views, respectively, of flex circuit optics and a corresponding encoder mask block;

FIGS. **18**A-B are front and back perspective views of a further double-bearing position encoder assembly;

FIGS. **19**A-B are top and bottom partially exploded perspective views, respectively, of a further double-bearing position encoder assembly;

FIGS. **20**A-B are top mostly exploded and exploded perspective views, respectively, of a further double-bearing position encoder assembly;

FIGS. **21**A-B are front and perspective views, respectively, of a first encoder cylinder embodiment;

FIGS. **22**A-B are front and perspective views, respectively, of a second encoder cylinder embodiment; and

FIGS. **23**A-B are front and perspective views, respectively, of a third encoder cylinder embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Generally

FIGS. **3**-**23** illustrate three position-encoder embodiments. Each of these embodiments advantageously utilize a double-bearing axle to stably mount an optical encoding device for the most precise optical measurements of the axle angular position and, hence, the linear position versus time of a pulser **140** (FIG. **1**). In this manner, a precisely measured and controlled sensor active pulse can be generated.

FIGS. **3**A-B generally illustrate slotted-wheel, position-encoder **301**, **302** embodiments. The encoders **301**, **302** each have an axle **310** with a double-bearing **320** mount to a housing **330**. The slotted wheel **370** is mounted to the axle

310. LEDs **340** illuminate a wheel obverse side and detectors **350** sense the illumination through wheel slots on a wheel reverse side. A folded, slotted mask **361** is positioned on both sides of the slotted wheel **370** so that mask slots align with wheel slots at discrete axle positions. Accordingly, axle position pulses are generated as the axle **310** rotates the wheel **340** and the wheel slots alternately block and pass light, as generated and sensed with the LED/detector optics **340**, **350**.

As shown in FIG. **3**A, the LED/detector optics **340**, **350** are located perpendicular to the slotted wheel, and the mask **361** is reflective. A slotted wheel position encoder embodiment according to FIG. **3**A is described in detail with respect to FIGS. **5-13**, below.

As shown in FIG. **3**B, the LED/detector optics **340**, **350** are located parallel to the slotted wheel so as to directly illuminate and sense via the mask **362**. A slotted wheel position encoder embodiment according to FIG. **3**B is described in detail with respect to FIGS. **14-17**, below.

FIG. **4** generally illustrates a reflective-cylinder, position-encoder **400** embodiment. The encoder **400** has an axle **410** with a double-bearing **420** mount to a housing **430**. A reflective cylinder **440** is mounted to the axle **410**. The cylinder surface has a repetitive reflective structure disposed across the length of the cylinder. A commercial optical encoder **450** is located over the cylinder so as to sense the reflective structure **440** and determine axle position accordingly. In an embodiment, the optical encoder is a 3-channel reflective incremental encoder available from Avago Technologies, San Jose, Calif. A reflective cylinder position encoder embodiment according to FIG. **4** is described in detail with respect to FIGS. **18-23**, below.

Slotted Wheel Encoder—Indirect Illumination Encoder Mask

FIGS. **5-13** illustrate details of a double-bearing, slotted-wheel, position-encoder embodiment utilizing an indirectly-illuminated (indirect) encoder mask. FIGS. **5-6** illustrate the double-bearing position encoder **500** assembly which reads an encoder wheel **900** via a wheel-edge-mounted photo interrupter **610**. The encoder wheel **900** is part of an encoder assembly **620**. The encoder assembly **620** is advantageously mounted within an double-bearing encoder housing **1000**, **1100**. The photo interrupter **610** includes an encoder mask block **700** that houses a reflective encoder mask (origami) **800**, LEDs **1310** and detectors **1320**. The LEDs **1310** and detectors **1320** are mechanically mounted to, and in electrical communications with, a flex circuit **1200** that generates LED **1310** drive signals and receives and processes detector **1320** signals. The encoder assembly **620** has a encoder wheel **900** mounted between encoder wheel bushings **626** and shaft bushings **624**. The photo interrupter **610** is mounted onto the encoder housing **1000**, **1100** over an encoder wheel **900** edge.

FIGS. **7**A-E illustrate an encoder mask block **700** that houses the flex circuit-mounted optics **1310**, **1320** (FIGS. **13**A-B) proximate to the encoder mask **800** (FIGS. **8**A-D). FIGS. **8**A-D illustrate the encoder mask **800**, which defines an encoder wheel path **810**, reflective surfaces **820** and mask slots **830**. The encoder mask allows the LEDs/detectors **1310**, **1320** (FIG. **13**B) to read the wheel slots at 0 and 90 electrical degrees. In particular, LED **1310** (FIG. **13**B) light is reflected off one surface **820** through the slots **830** and intermittently through the encoder slots **920** as the encoder **900** spins within the wheel path **810**. The intermittent light is reflected off another surface **820** to the detectors **1320** (FIG. **13**B). FIGS. **9**A-D illustrate a slotted encoder wheel **900** constructed as a thin, round disk defining a center-mount hole **910**, encoder slots **920** and an index slot **930**.

FIGS. **10-11** illustrate the encoder front housing **1000** and back housing **1100** that advantageously provides a double-bear mount for the encoder assembly **620** (FIGS. **6**A-B). Further the housing **1000**, **1100** positions the photo interrupter **610** (FIGS. **6**A-B) over the encoder wheel **900** so as to detect the passing encoder slots **920** (FIGS. **9**A-D). FIGS. **12-13** illustrate the encoder flex circuit assembly **1200** and corresponding optics **1300** and mask block **700**, which generate signals responsive to the encoder **900** (FIGS. **9**A-D) position as it rotates in response to a shaft-coupled, motor-driven active pulser **110**, **120**, **140** (FIG. **1**).

Slotted Wheel Encoder—Direct Illumination Mask

FIGS. **14-17** illustrate details of a double-bearing, slotted-wheel, position-encoder **1400** embodiment utilizing a direct illumination encoder mask. FIGS. **15**A-D illustrate an encoder mask block **1500** that positions flex circuit-mounted optics to the mask **1600** (FIGS. **16**A-D). FIGS. **16**A-D illustrate the encoder mask origami **1600** having mask slots for reading the wheel slots at 0 and 90 electrical degrees. FIGS. **17**A-B illustrate flex circuit optics **1700** and the corresponding encoder mask block **1500** (FIGS. **15**A-D).

As shown in FIGS. **14**A-B, a double-bearing position encoder **1400** assembly reads an encoder wheel portion of an encoder assembly **1420** via a wheel-edge-mounted direct illumination mask **1600** and proximate-mounted LED/detector optics **1700** (FIGS. **17**A-B). The encoder assembly **1420** is advantageously mounted within an double-bearing encoder housing **1401**, **1402**. A photo interrupter includes an encoder mask block **1500** that houses a direct illumination encoder mask **1600**, LEDs **1710** (FIG. **17**B) and detectors **1720** (FIG. **17**B). The LEDs and detectors are mechanically mounted to, and in electrical communications with, a flex circuit **1701** that generates LED drive signals and receives and processes detector signals. The encoder assembly **1420** has a encoder wheel mounted between encoder wheel bushings and shaft bushings as described above. The photo interrupter **1500**, **1600** is mounted onto the encoder housing **1401**, **1402** over an encoder wheel edge.

FIGS. **15**A-D illustrate an encoder mask block **1500** that houses the flex circuit-mounted optics **1710**, **1720** (FIG. **17**B) proximate to the encoder mask **1600** (FIGS. **16**A-D). FIGS. **16**A-D illustrate the encoder mask **1600**, which defines an encoder wheel path **1610**, a direct optical path **1620** and mask slots **1630**. The encoder mask allows the LEDs/detectors **1710**, **1720** (FIG. **17**B) to read the wheel slots at 0 and 90 electrical degrees. In particular, LED **1710** (FIG. **13**B) light is directly transmitted **1620** through the slots **1630** and intermittently through the encoder slots **920** (FIG. **9**B) as the encoder spins within the wheel path **1610**. The intermittent light is directly transmitted **1620** to the detectors **1720** (FIG. **17**B).

Reflective Cylinder Encoder

FIG. **18-23** illustrate details of double-bearing, reflective cylinder, position-encoder **1800** embodiment utilizing an off-the-shelf reflective encoder **1810** mounted proximate a double-bearing reflective encoder cylinder **2100-2300** (FIGS. **21-23**). FIGS. **18-20** illustrate the double-bearing position encoder **1800** embodiment having an off-the-shelf reflective encoder **1810**, an encoder block **1820** and a reflective encoder cylinder **2100-2300**. FIGS. **21-23** illustrate various encoder cylinder embodiments.

A double-bearing position encoder has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to limit the scope of the claims that follow. One of ordinary skill in the art will appreciate many variations and modifications.

What is claimed is:

1. A double-bearing position encoder comprising:
a housing;
a plurality of bearings disposed within the housing;
an axle disposed within the housing and supported by the bearings, wherein the axle is in mechanical communications with a rotating cam that actuates a pulser so as to generate an active pulse at a tissue site for analysis by an optical sensor;
an encoder coupled to the axle and comprising an encoder slot;
an encoder mask comprising a mask slot, wherein encoder mask extends over an edge and at least partially along two sides of the encoder;
a light source configured to emit light; and
a detector configured to:
detect the light after the light passes through the encoder slot, passes through the mask slot, and reflects off a portion of the encoder mask at least one time, and
generate a signal that is responsive to the detected light, wherein the signal is indicative of at least one of a frequency or a phase of the active pulse.

2. The double-bearing position encoder of claim **1**, wherein the light reflects off of the portion of the encoder mask prior to passing through at least one of the encoder slot or the mask slot.

3. The double-bearing position encoder of claim **1**, wherein the light reflects off of the portion of the encoder mask after passing through at least one of the encoder slot or the mask slot.

4. The double-bearing position encoder of claim **1**, wherein the light reflects off of a first portion of the encoder mask prior to passing through the encoder slot, and wherein the light reflects off of a second portion of the encoder mask after passing through the encoder slot and prior to reaching the detector.

5. The double-bearing position encoder of claim **1**, wherein the encoder slot is a first encoder slot, wherein the encoder comprises a plurality of encoder slots including the first encoder slot.

6. A method for determining at least one of a frequency or a phase of an active pulse generated by an optical sensor, the method comprising:
detecting light emitted by an emitter after the light passes through an encoder slot of an encoder, passes through a mask slot of the encoder mask, and reflects off a portion of the encoder mask at least one time, wherein the encoder is coupled to an axle supported by at least two bearings, wherein the axle is in mechanical communications with a rotating cam that actuates a pulser so as to generate an active pulse at a tissue site for analysis by an optical sensor; and
generating, using a detector, a signal that is responsive to the detected light, wherein the signal is indicative of at least one of a frequency or a phase of the active pulse.

7. The method of claim **6**, further comprising:
electronically determining a position of the encoder based at least in part on the signal generated by the detector; and
electronically determining the at least one of the frequency or the phase of the pulser based at least in part on the position of the encoder.

8. The method of claim **6**, wherein the pulser comprises a mechanical element configured to perturb the tissue site at a predetermined periodicity.

9. The method of claim **6**, wherein the light reflects off of the portion of the encoder mask prior to passing through at least one of the encoder slot or the mask slot and prior to reaching the detector.

10. The method of claim **6**, wherein the light reflects off of the portion of the encoder mask after passing through at least one of the encoder slot or the mask slot and prior to reaching the detector.

11. The method of claim **6**, wherein the light reflects off of a first portion of the encoder mask prior to passing through the encoder slot, and wherein the light reflects off of a second portion of the encoder mask after passing through the encoder slot and prior to reaching the detector.

12. A noninvasive optical sensor comprising:
a pulser comprising a mechanical element configured to perturb tissue of a patient at a measurement site at a predetermined periodicity,
an encoder comprising an encoder slot,
an encoder mask comprising a mask slot, wherein encoder mask extends over an edge and at least partially along two sides of the encoder,
an axle supported by at least two bearings, wherein rotation of the axle causes rotation of the encoder, and wherein rotation of the axle further causes actuation of the pulser so as to generate an active pulse at the measurement site,
a light source configured to emit light, and
a detector configured to:
detect the light after the light passes through the encoder slot, passes through the mask slot, and reflects off a portion of the encoder mask at least one time, and
generate a signal that is responsive to the detected light, wherein the signal is indicative of at least one of a frequency or a phase of the active pulse.

13. The noninvasive optical sensor of claim **12**, wherein the light source is a first light source, wherein the detector is a first detector, where the light is a first light, wherein the signal is a first signal, and wherein the noninvasive optical sensor further comprises:
a second light source configured to emit second light;
a second detector configured to detect the second light after attenuation by tissue of the patient and output a second signal that is responsive to the detected second light, wherein the second signal is indicative of a physiological parameter of the patient.

14. The noninvasive optical sensor of claim **12**, wherein the mask slot of the encoder mask is configured to intermittently align with the encoder slot of the encoder to permit the passing of the light.

15. The noninvasive optical sensor of claim **12**, wherein the light reflects off of the portion of the encoder mask prior to passing through at least one of the encoder slot or the mask slot.

16. The noninvasive optical sensor of claim **12**, wherein the light reflects off of the portion of the encoder mask after passing through at least one of the encoder slot or the mask slot.

17. The noninvasive optical sensor of claim **12**, wherein the light reflects off of a first portion of the encoder mask prior to passing through the encoder slot, and wherein the light reflects off of a second portion of the encoder mask after passing through the encoder slot and prior to reaching the detector.

18. The noninvasive optical sensor of claim **12**, wherein the light reflects off of the encoder mask twice prior to passing reaching the detector.

19. The noninvasive optical sensor of claim **12**, wherein the encoder slot is a first encoder slot, wherein the encoder comprises a plurality of encoder slots including the first encoder slot.

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